PROJECT SCALE EFFECTIVENESS MONITORING IN THE SOUTH FORK WAGES CREEK WATERSHED

Principal Investigator:

Graham Matthews, Principal Hydrologist, Graham Matthews & Associates, P.O. Box 1516, Weaverville, CA; (530)-623-5327

Cooperators:

Stephen P. Levesque, Forest Hydrologist, Hawthorne Timber Company / Campbell Timberland Management P.O. Box 1228, Fort Bragg, CA; (707) 961-3302

Peter H. Cafferata, Forest Hydrologist, California Department of Forestry and Fire Protection, P.O. Box 944246, Sacramento, CA; (916) 653-9455

Background:

One of the primary goals of monitoring programs developed by the Board of Forestry and Fire Protection (BOF) is to assess the effectiveness of the Forest Practice Program (i.e., the Rules and the Review Process) in protecting the beneficial uses of water. The BOF's Monitoring Study Group (MSG) has concluded that instream monitoring has the ability to assess current condition and long term trends in channel conditions and that the best way to document these trends is through the establishment of *cooperative monitoring watersheds*. Due to increasing needs for information relative to forest management and coho salmon fish habitat because of the federal listing, cooperative monitoring watersheds within the range of this fish are of primary interest to the MSG. In these basins, private landowners and government agencies will work together on both instream and hillslope monitoring using mutually acceptable protocols, quality assurance, and quality control standards. As a result of this cooperation, landowners will gain mutually acceptable and verifiable data on how their practices are impacting water quality and coldwater fisheries. The overall goal in coastal watersheds is to improve habitat conditions for declining numbers of anadromous fishes.

The instream component of this cooperative project will provide information on the condition and trend of instream parameters based on periodic measurements in selected sub-watersheds. This will be combined with implementation and effectiveness monitoring of the Rules at various hillslope locations subject to timber operations. Conclusions regarding the Rules and instream conditions will be based on measurements made over several years. For example, if channel conditions show recovery through a range of climatic events, it may be concluded that modern hillslope forestry practices are not degrading the aquatic ecosystem. Collection of instream monitoring and hillslope monitoring data will both occur as part of this project.

Due to limited state and federal budgets, the cooperative monitoring watershed approach appears to be a primary method of accomplishing the needs of the BOF. Other potential benefits of cooperative monitoring watersheds include testing and refinement of alternative or additional hillslope and instream monitoring techniques.

Opportunities to implement this cooperative monitoring approach are currently available on the Hawthorne Timber Company ownership (Hawthorne). Hawthorne, managed by Campbell Timberland Management, owns approximately 184,000 acres of commercial timberlands in Mendocino County (Figure 1).

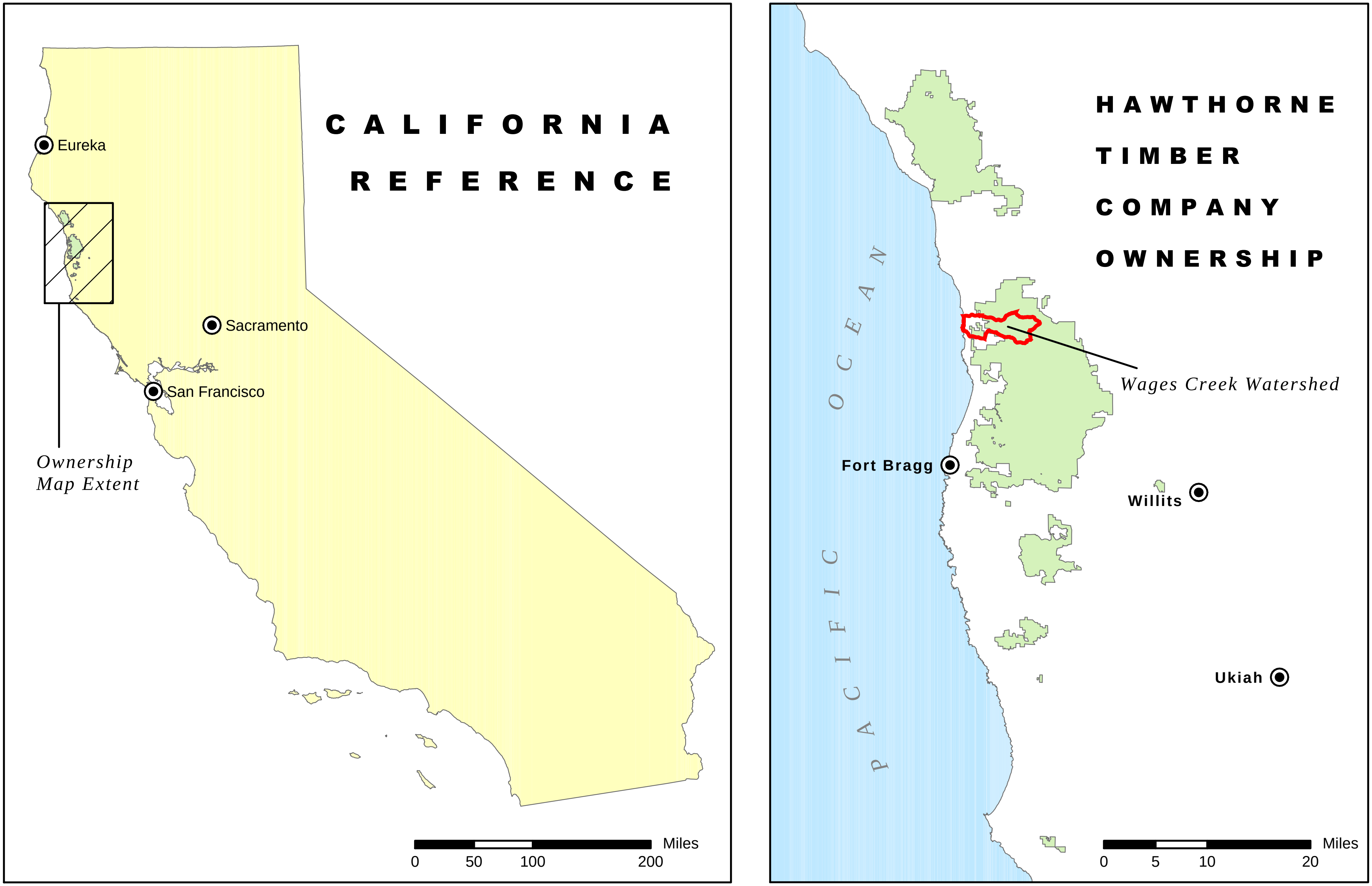

Figure 1. Regional Vicinity Map for The Hawthorne Timber Company

Hawthorne Timberlands
(Total Acres = 184,168)

Wages Creek Watershed
(Total Acres = 8,583)

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The science staff at Campbell Timberland Management shares the interest and need to verify to what extent (and by what causal mechanisms) current forest practices are increasing the rate of sediment delivery to the stream network. However, the literature suggests that the determination of hillslope erosion rates associated with current management practices compared to natural background erosion rates (particularly from mass wasting events) is virtually impossible at small spatial scales (project/THP) and over short time scales (USFS 2002). It is important that the limitations of science are given full consideration in this endeavor.

To intelligently conduct water quality monitoring in mountain drainage basins at the project (THP) scale, it is necessary to establish pre-logging (background) water quality conditions. This alone renders the idea of quantitative measurement programs of turbidity at the project scale extremely problematic. In the absence of pre-logging water quality data, Campbell proposes to treat South Fork of Wages creek as an experimental watershed, collecting three years of pre-treatment data to establish “ambient” conditions. At the end of this pre-treatment period, Hawthorne will implement a Timber Harvest Plan consistent with standard operational practices. Without question, this research will better inform Campbell staff in their efforts to develop and implement effective prescriptions for reducing sediment generation in a watershed recovering for historic land use practices.

Problem/Hypothesis:

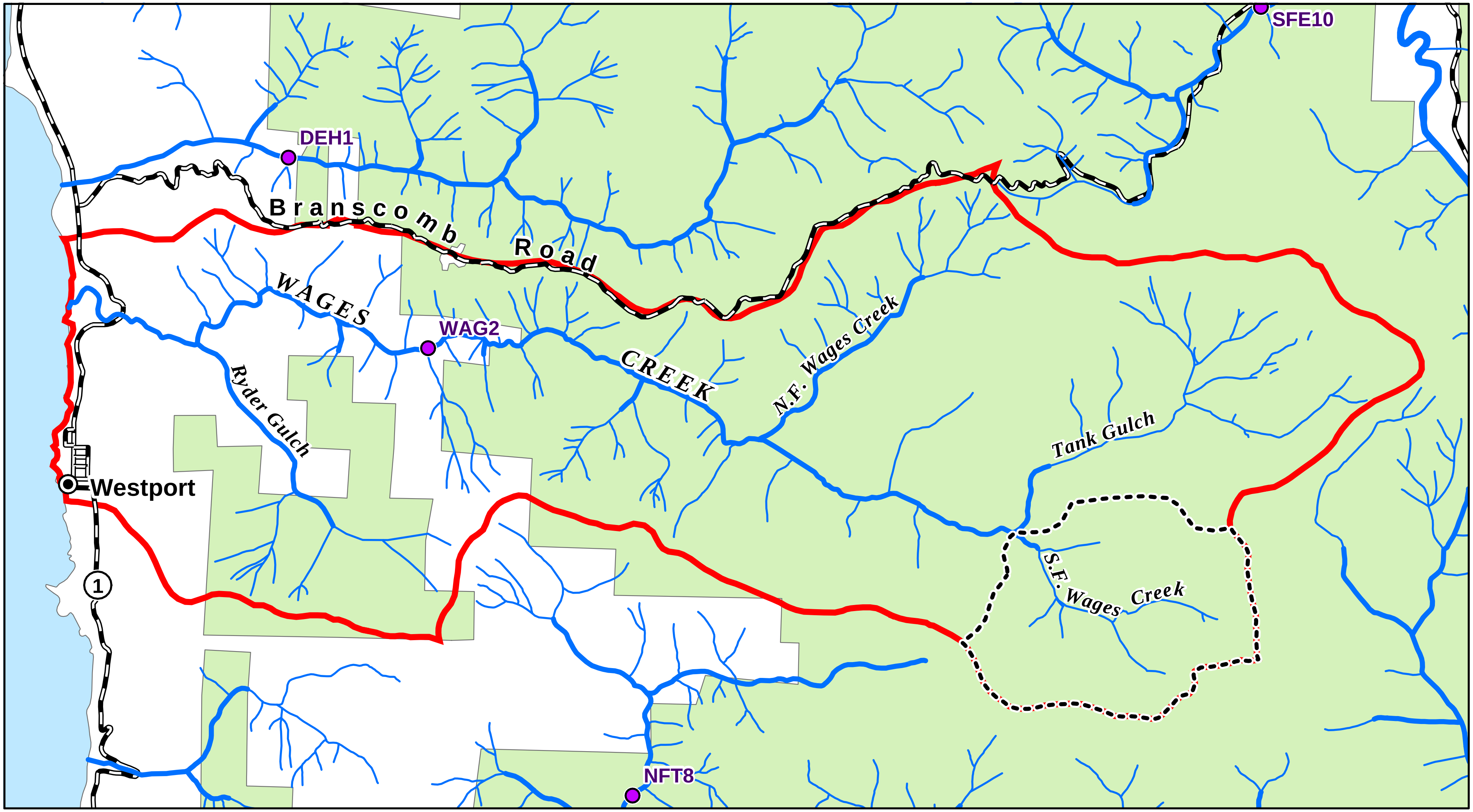
Accelerated surface erosion from land management activities is well recognized. Erosion from road surfaces is often a persistent source of sediment in logged basins due to the large network of native surface roads associated with harvest activities and the increased connectivity of the roads to the stream channels. Numerous studies have documented the role of road construction in increased sediment yields (Reid and Dunne 1984, Rice et al. 1979). Road-related sediment is a major factor in most North Coast watersheds. The location of roads on basin slopes (near stream, mid-slope, and ridge top) can have major effects on both fluvial and mass wasting processes (Cafferata and Spittler 1998, Jones et al. 2000).

Studies describing the negative impacts on water quality from forest management activities and road networks are well represented in the literature. However, the effects of recent substantial changes in the methods of Timber Harvesting Plan (THP) implementation have not been subject to detailed instream effectiveness monitoring. Failure to distinguish between the effects of legacy management activities and present state-of-the-art THP implementation methods, particularly road rehabilitation, has hindered full understanding of the effects of current practices as they affect stream health and reflect watershed condition.

Study Area

Wages Creek Watershed

Wages Creek is located in Mendocino County, intersecting HWY 1 approximately two miles north of Westport, California (Figure 2). The legal description to the mouth is T21N R17W SEC 29 (Calwater Version 2.2 #1113.120202, Ryder Gulch). Hawthorne owns 8.2 sq mi. of the 13.41 sq mi. drainage area. The basin contains four Class 1 watercourses: Ryder Gulch, North Fork Wages, South Fork Wages and Tank Gulch. Elevations over the entire watershed range from sea level at the mouth to approximately 2,660 feet in the headwaters. The hardwood canopy is comprised of tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*), while the conifer canopy includes redwood (*Sequoia semperviren*) and Douglas- fir (*Pseudotsuga menziesii*). A more detailed assessment of watershed characteristics and land-use history is provided in Appendix A (Barber 1997).



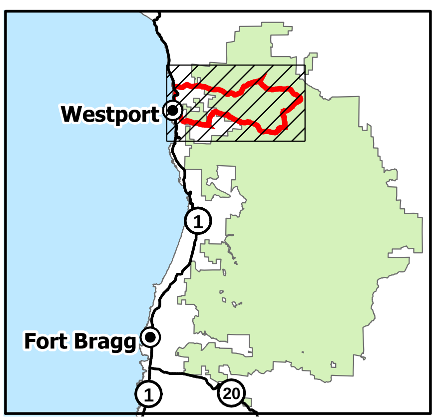


Figure 2. Local Vicinity Map - S.F. Wages Creek Effectiveness Monitoring Project

Wages Creek Watershed
(Total Acres = 8,583)

Hawthorne Timberlands
(Total Acres in Wages Creek Watershed = 6,657)

Effectiveness Monitoring Project
(Total Acres in S.F. Wages Creek Watershed = 907)

Road Surface

Paved

Watercourses

Class I

Class II

Index Monitoring Reach Location

0 0.5 1 2 Miles

1:50,000

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Georgia Pacific Corporation initiated a property-wide aquatic monitoring program in 1993[1]. As part of this program, an indexed monitoring reach was established in the mainstem of lower Wages Creek (Figure 2). A total of eight McNiel sediment samples are taken from two separate riffles on an annual basis during the low-flow period. Samples are wet-sieved in the field and analyzed to determine what fraction of the sample consisted of sediment particles less than 0.85 mm in diameter (Table 1). Instantaneous water temperatures are recorded with Hobo data loggers. Data are analyzed to determine the Maximum Weekly Average Temperature (MWAT) for each year sampled (Table 1). As expected, a strong coastal influence greatly moderates the thermal regime in Wages Creek. Temperature is clearly not a limiting factor for salmonids in this watershed.

Table 1. Monitoring Results at Index Reach WAG2, Wages Creek. 1993-2002.

Sample Year	Fine Sediment (% < 0.85 mm)	Water Temperature (MWAT)
1993	Not Sampled	13.9
1994	Not Sampled	14.8
1995	17.1	14.2
1996	18.7	14.9
1997	17.4	14.8
1998	15.5	14.1
1999	Not Sampled	14.1
2000	Not Sampled	13.9
2001	19.5	13.7
2002	14.5	Not Sampled

The presence of both coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) has been documented in the watershed consistently since 1995. California Department of Fish and Game staff also observed spawning king salmon (*O. tshawytscha*) in 2003. It is important to note that between 1995 and 1996, approximately 32,000 jeuvenile coho (Noyo River broodstock) were planted in Wages Creek. Unfortunately, there is not enough species and life-stage specific information available to evaluate the overall viability of the current populations.

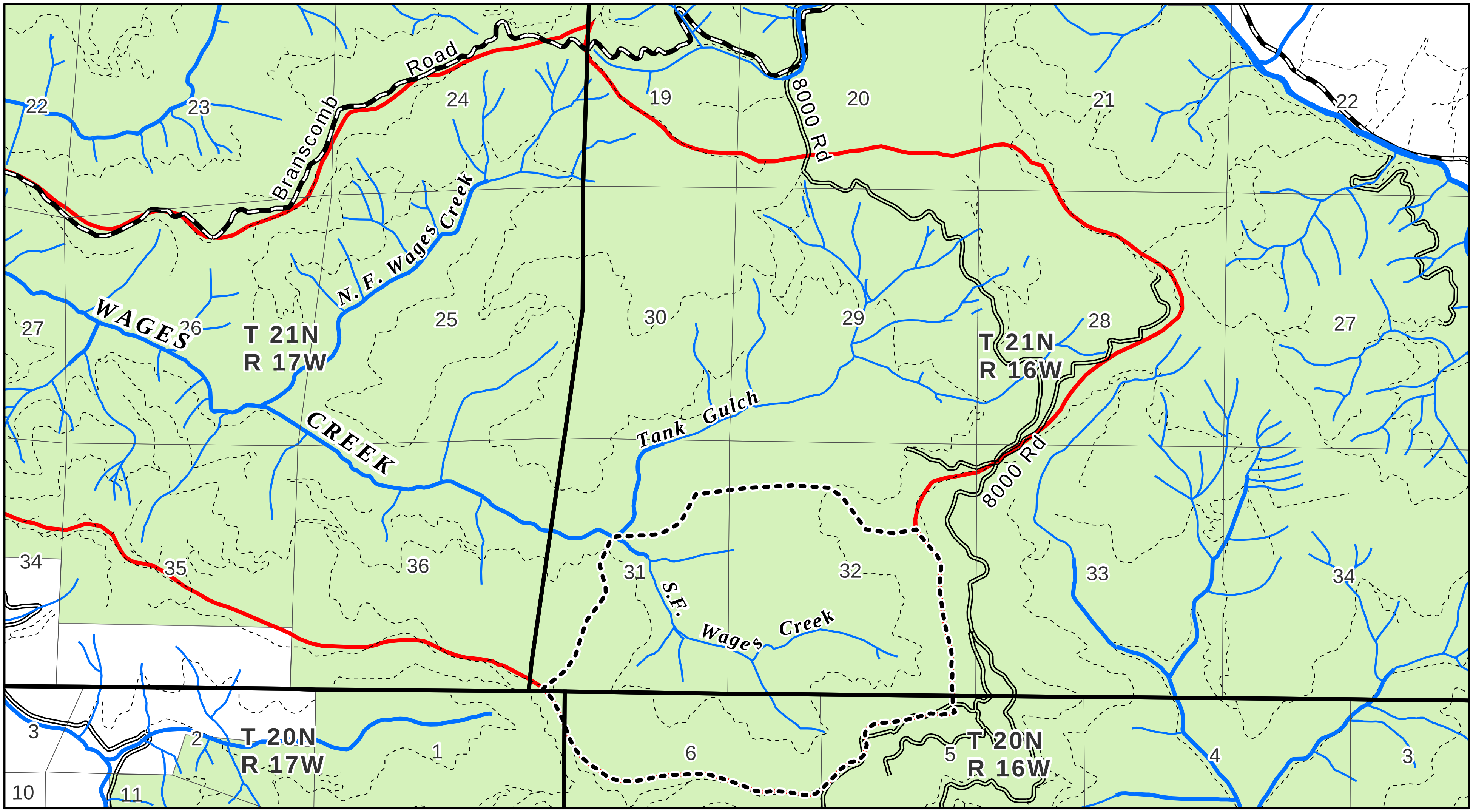
South Fork Wages Creek Sub-Watershed

The 907-acre South Fork Wages Creek sub-watershed has been selected for study after careful review of the Hawthorne property (Figure 3). Ultimately, this location was selected for four primary reasons:

- There has not been intense timber harvest activity in the sub-watershed since 1974.
- The 1960's era mid-slope road with multiple stream crossings has not been upgraded.
- Presence of actively eroding features associated with the legacy of historic land use practices.
- The site is reasonably accessible in the winter period via the Branscomb Road.

Harvest history suggests the first entry into the South Fork Wages Creek sub-watershed occurred with the construction of stream adjacent and mid-slope roads prior to1962 (Figure 4). These roads enabled tractor logging of the entire basin to occur within a four-year period (Figure 5). Additional mid-slope road construction occurred in 1973 and 1974 to facilitate a tractor-yarded overstory removal harvest.

[1] Hawthorne has continued to monitor index reaches since acquiring the property in 1999.



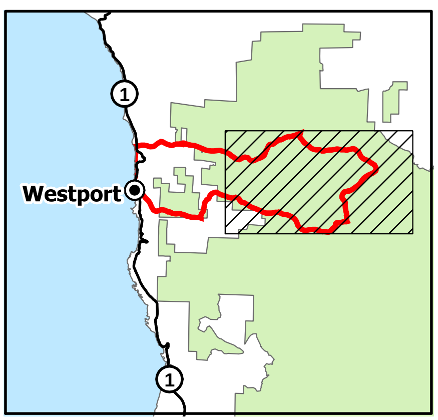


Figure 3. Location Map - S. F. Wages Creek Effectiveness Monitoring Project

Wages Creek Watershed
(Total Acres = 8,583)

Hawthorne Timberlands
(Total Acres in Wages Creek Watershed = 6,657)

Effectiveness Monitoring Project
(Total Acres in S. F. Wages Creek Watershed = 907)

Watercourses

Class I

Class II

Road Surface

Paved

Rocked

Dirt

0 1,500 3,000 6,000 Feet

1 inch equals 3,000 feet

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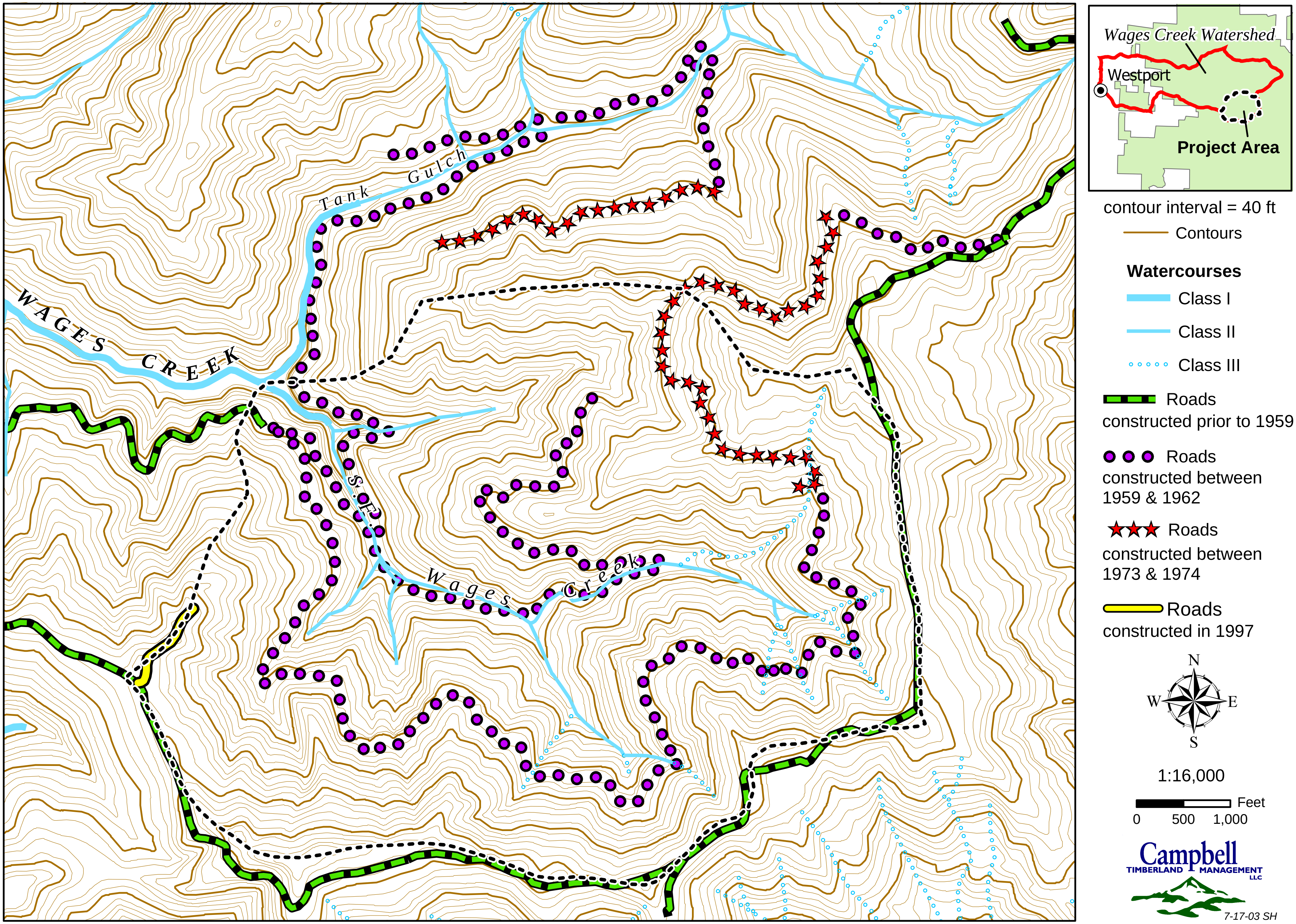
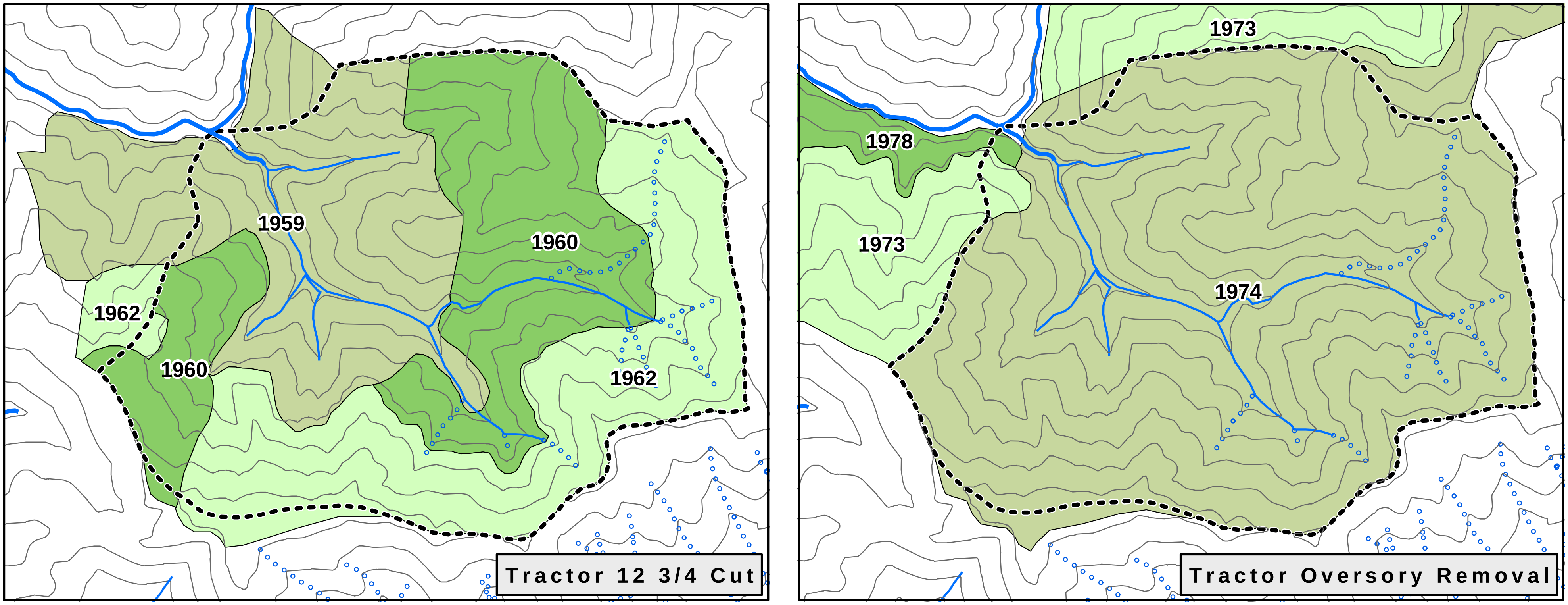
Figure 4. Road Construction History in the S. F. Wages Creek Watershed (Portion of Cal Water v2.2# - 113.120202)





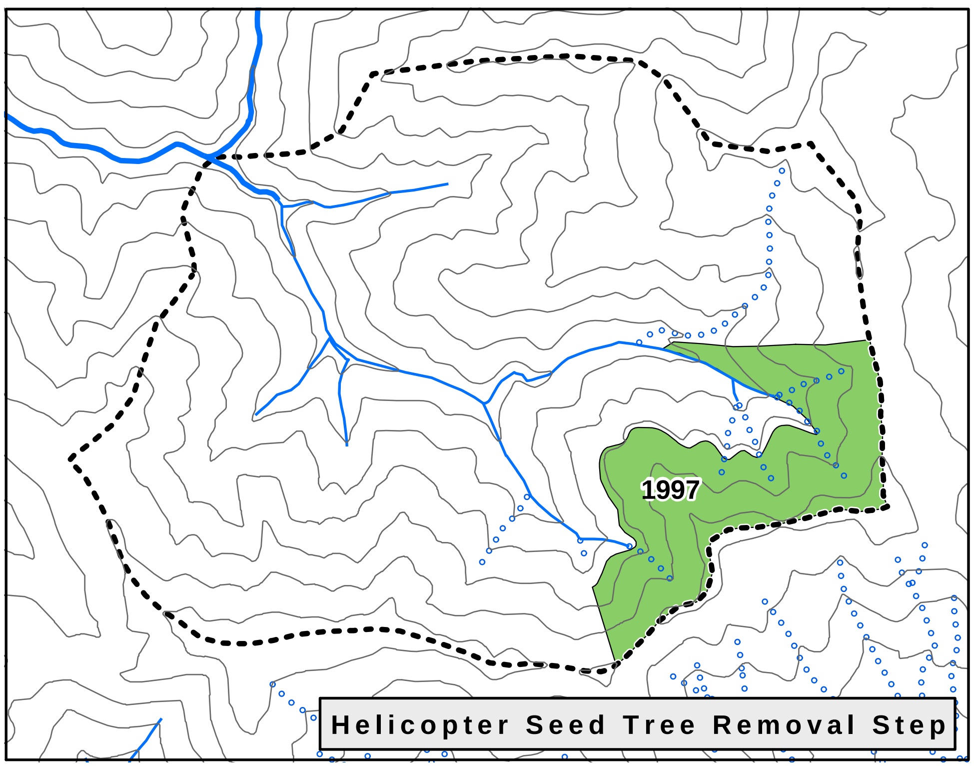


Figure 5. Timber Harvest History in the S. F. Wages Creek Watershed (Portion of Cal Water v2.2# - 113.120202)

Project Area

Contours 200 ft

Watercourses

Class I

Class II

Class III

N
W E
S

1:24,000

1 inch equals 2,000 feet

0 0.25 0.5 1 Miles

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Field observations confirmed the footprint left by the prior two harvests was consistent with observations in similar coastal watersheds on the Hawthorne property. Current stand conditions will support a future stand improvement harvest that will also be consist with methods Campbell is prescribing on current Timber Harvesting Plans for similar site conditions.

Objectives and Scope:

The objective of the proposed monitoring project is to establish the relative importance of sediment generated by THP activities, as currently practiced by Campbell Timberland Management, compared to legacy sources and background rates. Several hypotheses are planned for testing: (1) current harvest practices do not increase turbidity by 20% or more over pre-project background rates, (2) modern THP methods produce far less sediment than legacy effects in coastal watersheds, (3) appropriate levels of road rehabilitation are key elements of THP implementation if instream beneficial uses are to be protected.

The proposed monitoring project includes several types of water quality monitoring defined by the North Coast Regional Water Quality Control Board:

- **Trend monitoring** is used is used to characterize water quality conditions over time, usually on a large spatial scale. The trajectory of a particular parameter over time provides information about the effects that cumulative impacts may be having on that parameter.

- **Effectiveness monitoring** is used to determine whether particular land management prescriptions (e.g., erosion control measures, restrictions on activities in riparian zones, etc.) are effective at achieving desired results. Effectiveness monitoring is most appropriately conducted using a robust study design at a prescription scale.

- **Compliance monitoring** is used to determine whether discharges resulting from land use activities are in compliance with water quality standards. Compliance monitoring may be conducted at various spatial scales, but is most applicable at the project scale or smaller. Compliance monitoring may be considered a special case of effectiveness monitoring, since it may be used to determine whether particular land management practices are effective at meeting water quality standards.

- **Forensic monitoring** is used to identify pollutant sources for purposes of timely remedial action in the field. It is typically conducted on small spatial scales, as close to suspected pollutant sources as possible. Forensic monitoring is often designed such that certain instream conditions trigger field inspections. However, triggers for field inspections can also be event-driven (i.e., intense rainfall events).

The project will involve detailed watershed mapping of sediment sources as well as extensive stream gaging and sediment sampling over a lengthy study period. A high-resolution sediment budget will be developed, partially based on continuous turbidity and suspended sediment records. Suspended sediment and water discharge will be sampled on rising and falling limbs of flood hydrographs throughout the year, and sediment concentration will be analyzed by standard laboratory techniques (Guy 1969, Edwards and Glysson 1988). Quality Assurance Protocols developed for this proposed project are included in Appendix B.

The scope of this project is:

1. Install and operate 4 continuous streamflow/turbidity gages within the South Fork Wages Creek watershed along with up to 4 manual streamflow stations,
2. Conduct detailed geomorphic mapping of the study area and develop a preliminary sediment budget,
3. Collect streamflow, turbidity, and suspended sediment measurements during storm events,
4. Compute streamflow and sediment transport records for all sites and present data in a comprehensive annual data report.

TASK 1: Geomorphic Inventory and Preliminary Sediment Budget of the Entire Study Watershed

Base Map Preparation

Given the scale of the monitoring program proposed, extremely detailed topography is needed for identifying features, mapping all sites of erosion, and generally coordinating all study activities. To obtain topography at this resolution, LIDAR methods will be used to develop a 2 foot contour map of the entire study area. The primary advantage of LIDAR technology is the ability to "see" through vegetation to the landforms beneath.

At the same time, low-level color aerial photography will be flown to produce aerial base maps of the entire study area. Prior to the flight, ground targets located using survey-grade GPS will be set to allow development of orthophotos of the project area. Both of these tasks will not be completed in Year 1 due to funding limitations and the need to purchase, install, and operate gaging equipment.

Development of a Sediment Budget

Preparation of a preliminary sediment budget (Swanson et al. 1982, Reid and Dunne 1996) for the study area is one of the primary first year tasks. An analysis of the relative contributions of sediment from different sources is valuable in understanding the interactions between natural conditions, land use activities, and resource conditions.

Typically, a sediment budget quantifies sediment sources (inputs) by each erosional process, as well as changes in the amount of channel-stored sediment, and sediment outputs as measured at a gaging station over a designated time frame or several time periods (Reid and Dunne, 1996). Quantifying sediment sources involves determining the volume of sediment delivered to stream channels by the variety of erosional processes operating within the watershed. For the South Fork Wages Creek study area, these can be divided into three primary processes or sediment delivery mechanisms: 1) mass movement (landslides), 2) fluvial erosion (gullies, road and skid trail crossing failures, and stream bank erosion), and 3) surface erosion (rills and sheetwash).

These three processes can deliver sediment to stream channels both naturally and as a result of land use activities. Sediment production by mass movement processes occurs commonly during large, infrequent storm events, whereas fluvial and surface erosional processes can occur during small storms in virtually every water year or as a result of large storms. Direct sedimentation into stream channels by heavy equipment involved with road/railroad construction and timber harvest was probably commonplace in the study area prior to 1974. Some areas may still be experiencing elevated sediment yields as a legacy of the former practices (Koehler et al. 2001). The residence time of such introduced sediments is highly variable, but may well be on the order of decades to centuries.

Changes in the amount of sediment stored in stream channels are usually measured in the field by analyzing surveyed channel cross sections or by field surveys which estimate the amount of past channel filling and subsequent downcutting that has occurred. Analyzing changes in channel stored sediment can answer questions such as how much of what type of sediment is transported and where is it deposited, how does introduced sediment interact with sediment which was already in storage in the channel, and how does the transport affect overall stream morphology (Reid and Dunne 1996).

Erosion Feature Inventory
Given the objectives of this project, a complete inventory of the study area will be made for the sediment budget. Field personnel will map all erosional features within the boundaries of the study area by walking its entire area. Each feature will have the following data recorded: (1) type of sediment source, (2) any apparent land use or management associations, (3) area, thickness and volume of erosion, (4) estimate of the percentage of sediment delivered to the stream, (5) estimate of the age of the feature , and (6) specific location characteristics such as geomorphic form, hillslope steepness, dominant vegetation, and canopy cover. All data will be entered on a data form that will then be input into the project database.

Data analysis includes evaluation of sediment delivery by process (slides, gullies, rill erosion, bank erosion) and by land use association (non-management, harvest-related, road/skid-trail related). Data collected will allow differentiation between system roads (currently in use) and abandoned or legacy roads and other legacy features (e.g., landings, etc).

The individual sediment budget items are discussed below:

Landslides
Landslides will be mapped following standard geologic protocols. All landslide features in the study area will be located, placed on the base map, and attributes measured.

Roads
Field Inventory will be used to verify traffic and surfacing information, to verify segment types and grouping, to determine road attributes (tread, ditch, cutslope, fillslope) and prism dimensions, to collect information on cover percentage on cut- and fill-slopes, to review localized problem areas, and to determine potential delivery to streams. During field surveys, information on road sediment delivery will also be collected for each segment. At each drainage site, the potential for sediment delivery to the stream will be determined. Each drainage feature on a surveyed reach of road will be considered a site with a completed site sheet.

Drainage feature types include: watercourse crossings, ditch relief culverts, rolling dips, and waterbars. Road attributes affecting the amount of sediment produced from the road segment will be recorded. A delivery percentage will then be assigned to the site. Delivery is based on the road shape (insloped, outsloped, crowned), distance to stream, and geomorphic evidence of connectivity (gullies and rills). Other sources of erosion directly related to the drainage feature will also be recorded on the site sheet. Other erosional features associated with the road prism include: cut bank failures, fill failures, crossing failures, and gullies. Site sheets will also be filled out at every erosional feature not directly associated with a drainage feature.

Surface Erosion
Surface erosion beyond that derived from road surface erosion is primarily hillslope erosion from skid roads and harvest areas. Surface erosion will be estimated based on rill dimensions and the extent of exposed soil.

Bank Erosion
In order to quantify the amount of sediment contributed to stream channels from bank erosion, all reaches of channels within the study area will be inventoried for past erosion. Stream length and site location will be identified using a tape, hip chain or range finder and aerial photography mapping. All apparent erosional features will be recorded. Features will be given a volume, delivery percentage, and an age.

Alluvial Channel Storage
Sediment generated from upslope processes are transported through downstream reaches and frequently stored in landforms of various ages and often behind woody debris jams. In order to develop a sediment budget, an evaluation of changes in alluvial channel storage must be made. In narrow, low-order tributary channels, opportunities for significant storage of alluvial deposits are often limited. Areas with substantial alluvial deposits will be mapped using standard total station survey equipment, and will include, at a minimum a series of cross sections and a long profile.

Development of Project GIS
All sites identified in the sediment budget will be located precisely on the detailed base maps and entered into the project GIS database.

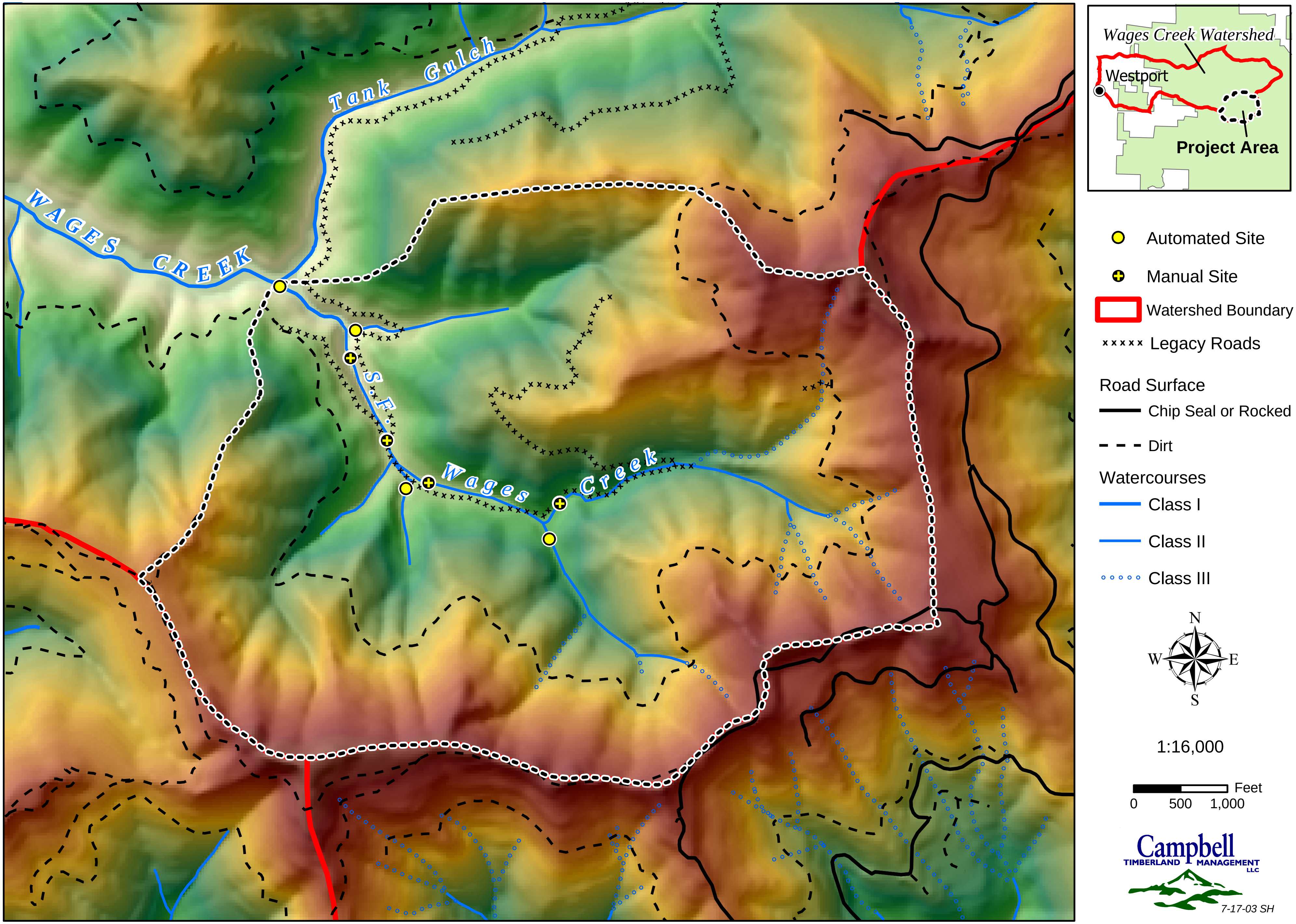
TASK 2: Establish the Gaging Station Network

The gaging network will consist of continuous and manual sites. The current program consists of 4 continuous and up to 4 manual stations (Figure 6). After final selection of each proposed gage site, staff gages will be installed to provide permanent stage datum. Due to the size of the channels in the study area, one staff plate will be installed which should allow stage measurement for virtually all flows. The staff plates are standard Type C enameled gages, installed on channel iron driven into the edge of the streambank. After staff plate installation, a station benchmark is established and surveys are made between these reference marks and the staff plates to provide a permanent datum record. A crest-stage gage (CSG) will also be mounted on the channel iron to provide records of peak flow stage for manual sites, or as a back-up to the sites with continuous stage recorders. The continuous recording stations will consist of a datalogger, pressure transducer, recording turbidimeter, as well as a staff gage, crest-stage gage, turbidity boom, and a small equipment house.

The datalogger (a Campbell Scientific CR510 unit) will be installed in a 2’x3’ steel enclosure to prevent vandalism and provide a secure area to hold deep cycle batteries, and excess cable. A bank-mounted boom will be fabricated and installed to allow operation of the turbidity sensor at the same relative position in the water column during a wide range of stages, and will follow USDA Forest Service Pacific Southwest Research Station (Redwood Sciences Laboratory) guidelines . The pressure transducer (Design Analysis H-310), with an accuracy of 0.025%, will be installed in flexible armored conduit down the streambank near the staff plate. The turbidity sensors to be installed are Forest Technologies Systems DTS-12 units with wipers. An ISCO 6700 series pumping sampler will be installed at each continuous site and connected to the datalogger.

A number of the sites will need improvement of the channel at the gage location in order to collect reliable streamflow data. At these sites, small weirs will be constructed using on-site rock and imported concrete. Small sampling bridges will be constructed to allow high flow measurements where needed and access along the channel for field personnel movement between sites during storms.

Figure 6. S.F. Wages Creek Watershed - Instream Sampling Locations (Portion of Cal Water v2.2# - 113.120202)



TASK 3: Operate and Maintain Streamflow Gages

Gage operation at the 4 continuous sites and 4 manual sites will begin October 1, 2003 and continue thereafter through the study period. Many of the sites with smaller drainage areas are ephemeral. No attempt will be made to collect streamflow data at very low flows, except along the mainstem. Gage data downloading and station maintenance will typically occur on a monthly basis, although it is likely to be considerably more often during winter months when field personnel are on-site often collecting data during storm events. Discharge measurements will be made at each site periodically during the fall, winter, and spring seasons. The measurements will be made using standard USGS streamflow measurement protocols, and we expect 8-12 discharge measurements to be collected at each site annually to define a satisfactory stage-discharge relationship. Equipment to be used includes Price AA and Pygmy velocity meters using an AquaCalc 5000 datalogger to record data. Measurements are summarized on a form similar to the standard USGS 9-207 form. After collection of the discharge measurements, a discharge-rating curve will be developed for each station by plotting the stage/discharge pairs and fitting a curve. The development of the stage-discharge relationship is completed using USGS standard protocols. All discharge measurements will follow USGS protocols and the Graham Matthews and Associates (GMA) Quality Assurance Project Plan (QAPP). If very high flows occur beyond the range of current meter measurements, a slope-area measurement will be made at each gaging stationsite for peak discharge determination. The QAPP for both the field and laboratory portions of this project will be submitted for approval to the project cooperators prior to the initiation of sampling.

TASK 4: Collect Sediment Data

At all study sites, sediment samples are needed to relate turbidity to suspended sediment loads, to calibrate the turbidity sensors, and to calibrate pumped samples versus cross-stream depth-integrated samples. It is expected that 80-100 sediment samples will be collected at each site during each water year, depending on the number of storms that occur. Samples will be collected at moderate flows by wading, which should be feasible at all sites in virtually all conditions. This program of sediment sampling will include both measurements of turbidity and suspended sediment. The continuous stations will be operated following the Turbidity Threshold Sampling (TTS) protocols developed by USFS, Pacific Southwest Research Station, Redwood Sciences Lab (Johnston et. al. 2001). Bedload sediment will not be sampled. In addition to sampling with pumping samplers, suspended sediment will be sampled with depth-integrating samplers (DH-48 or D-76), using procedures standardized by the USGS (Guy and Norman 1970, Edwards and Glysson 1988).

Suspended sediment samples will be taken to a suspended sediment lab for analysis. Turbidity values will be measured in the field shortly after data collection in order to meet the 48-hr EPA time frame for sample analysis. All samples will be analyzed for both turbidity and suspended sediment concentration following EPA and USGS/ASTM protocols. Per GMA protocols, a minimum of 10% of the samples will have replicates for QA/QC purposes.

TASK 5: Compute Streamflow and Sediment Transport Records

Continuous stage records will be combined with the stage-discharge relationships to compute continuous records of streamflow for all sites in the South Fork Wages Creek study area. The crest stage gages will allow measurement of storm peak discharges at other sites without continuous dataloggers. Data from the nearest continuous stations will be used to create synthetic hydrographs for the remaining manual stations. Streamflow results are will be summarized in a table of mean daily flows, and a table of instantaneous peaks above a selected base, while continuous (10-minute interval) stage and discharge data will be available electronically.

Continuous records of turbidity will come directly from the project turbidity sensors (10-minute intervals), while suspended sediment loads will be computed using the relationship between turbidity and suspended sediment developed from pumped and depth-integrated paired samples collected during storm events. Daily suspended sediment records will be computed by combining discharge data with the suspended sediment record developed from the continuous turbidity record.

TASK 6: Forensic Analysis of Sediment Delivery

Having staff on-site during significant storm events will allow forensic analysis of specific sediment delivery events. Large or unusual turbidity spikes will be tracked by the base station control datalogger and alarms will be triggered at pre-set thresholds to alert staff. Once a spike is identified, staff will walk the channel and/or hillslope in question in an attempt to locate the sediment source. New sites will be photographed, located on the detailed base maps, and volumes entrained estimated.

TASK 7: Report Preparation

This task involves preparing results of streamflow and sediment gaging at all of the sites and presenting these results and analyses in a technical report. The report will present all data collected, compare sediment loads for individual tributaries or basin areas, as well as from the South Fork Wages Creek study area as a whole. A separate report will be prepared for the geomorphic mapping and sediment budget developed in the first year.

TASK 8: Project Management and Meetings

This task includes project management by the cooperators , the geomorphic and hydrologic consultant, and Campbell Timberland Management. Items included are preparation of monthly progress reports, annual progress reports, and costs to attend semi-annual meeting regarding the project and preparation of presentations for such meetings. In addition, all aspects of project administration, such as contracts and billing, are also included in this task.

Expected Results/Products:

This monitoring project is expected to have a duration of 10 years.. Over the contract period, a series of deliverable products are required as listed below. At the conclusion of the study, a final report will be prepared that will include a comprehensive summary of the all geomorphic and hydrologic data and the analysis of these data.

Monthly: Brief progress report to accompany each monthly invoice.

Annual: Comprehensive report presenting all data collected in the previous water year, the results of data analysis, and conclusions to date.

Other Deliverables:

Geomorphic Mapping and Preliminary Sediment Budget Report after the second season of field work.

Peer reviewed publications at the completion of the study, or as appropriate, during the study. Such publications would include, at a minimum, a methods paper and a results paper.

Budget:

CDF will purchase the majority of the monitoring equipment, while Campbell will provide labor to operate the gages and collect streamflow, sediment transport, and geomorphic data. Capital equipment costs are approximately $40,000, while operating costs are also set at $40,000. Use of pump samplers is expected to reduce labor needs for sampling during storm events.

PROJECT SCHEDULE:

First Year (2003)	
Project Authorization	May 1, 2003
Site Recon for Installation Requirements	June 1
Order all long-lead time Equipment	June 1
Equipment Fabrication	September 1
Equipment arrives	September 15
Equipment Installation	September 15-October 1
Sediment Sampling	November 1-April 1
Gage Operation	October 1-April 30
First Year Report	June 30, 2004

Second Year (2004)	
LIDAR and color aerials	June 15, 2004
Geomorphic Mapping	July 1-August 30, 2004
Gage Operation	October 1-April 30
First Year Report	June 30, 2005

QUALIFICATIONS OF HYDROLOGY/GEOMORPHOLOGY CONSULTANT:

Graham Matthews & Associates (GMA) specializes in hydrologic and geomorphic data collection and analysis, as well as stream restoration project design and implementation. GMA is in a unique position to undertake this project based on experience, equipment, and personnel available. GMA currently operates 15 continuous streamflow gaging stations in the Wood River Valley of Oregon, 7 stations in the Trinity River basin, 5 in the South Fork Ten Mile, 2 in the Tahoe Basin, and 16 in the South Fork Trinity River watershed. GMA has collected hundreds of discharge measurements and thousands of sediment transport measurements in the last 5 years on a wide variety of streams and rivers. GMA has an outstanding array of state-of-the-art streamflow and sediment transport monitoring equipment and is able to fully equip at least 5 sampling teams and most equipment for 5 more individual hydrographers. GMA has installed over 10 turbidity threshold monitoring stations (TTS) in the last two years, and is currently operating 7 TTS stations for a variety of clients.

GMA has established a sediment lab that processes samples at a very reasonable cost while meeting strict laboratory procedures and QA/QC protocols. The lab participates in the USGS QA/QC program for suspended sediment concentration. GMA has implemented similar projects in the Trinity, South Fork Trinity, SF Ten Mile, and Wood River watersheds in recent years. GMA is led by Graham Matthews who has over 20 years experience in the fields of hydrology and geomorphology.

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APPENDIX A

WAGES CREEK WATERSHED CHARACTERISTICS AND LAND USE HISTORY

DRAFT

Sanitary Survey of Wages Creek

for Westport County Water District
Water System #2300730

by Teri J. Barber

5/23/97

THE FOLLOWING TEXT IS EXCERPTED FROM:

CHAPTER 2: WAGES CREEK WATERSHED AND WATER SUPPLY SYSTEM FOR WESTPORT, CALIFORNIA

Land Use and Natural Setting

Location. The Wages Creek watershed's place in the coast range is marked by the Pacific Ocean to the west, the community of Westport, on Highway 1 less than 1 mile to the south of Wages Creek, and Fort Bragg, 15 miles to the south of Wages Creek. The Branscomb community lies approximately 5 miles east of Wages Creek headwaters. Township Range and Sections comprising the Wages Creek watershed include T21N R17W sections 29, 30, 31, and 32; T21N R16 and 17 W sections 25-29, 32-36. A topographic basin map constructed from USGS 7.5 minute maps is included as Figure 2.

1. Major land uses

Pre-1800s: Native Americans called the Wailaki, a moving people of the local Pomo tribe which had a large center in Wolfe Creek near Usal, lived on Wages Creek's western ridge overlooking what is now Westport, at least seasonally. They fished on the beaches and brought much of their food back to the ridge to feed their people. They moved inland to fish the Eel river for their salmon season. A Westport resident, George Wages, grew up in Wages Creek. Dobbie Bowen suggested that in establishing an American name, George adopted the last name of the Alfred Wedges Family. He probably came to spell it w-a-g-e-s, after asking a literate person how to spell wedges, pronounced like wages. In geographical maps of the coastal areas of mendocino county, a tribe known as the coast Yuki, of Pomo background, lived in the Westport vicinity and may have inhabited Wages Creek. Dobbie Bowen, and Mike Stillwell, both of Wailaki origin, personal communications.

1800s: Wages Creek was named after Alfred Wedges, born circa 1828 in Kentucky, later coming to Big River and Westport. In the late 1800s the forest of Wages Creek was used to harvest tan bark from tanoak (Lithocarpus densiflora) and posts from coast redwood (Sequoia sempervirens). Tan oak bark was cut from the tree with a round type portable saw and transported by horse and mule out by the Old Wages Creek road to Wesport, as were hand split redwood posts. Tan bark and redwood posts were shipped by sea from Westport to San Francisco and other ports by Schooner. 1885 (Mendocino Historical Review, 1974). Lumber milled in Wages Creek was carried out by 6-horse wagons to Westport, and was shipped out by Schooner.

Early 1900s: The railroad came to Westport in the 1920's and laid track along the Old Wages Creek Road, which ran along the south side of Wages Creek Road a ways up the mountain, with a bridge across Rider Gulch. Barbara Barnard says they cut a new road against the side of the northern mountain in its present location for horse and buggy traffic on a temporary basis, saying the old road would eventually be restored, but the old road was never was restored. Once *complete, railroad transported ties and redwood products from three mills in Wages Creek. In addition to the mills, there was a large cookhouse to feed the tie-makers, mill workers and railroad workers up at the Wages Creek forks. The ties and posts were split up in the woods and carried down hill on sleds pulled by horses. Barbara was born in the old cabin (approximately 1920) now owned by Kisliuk (Barbara Barnard, personal communication)*

Mid 1900s: Much of the watershed was massively logged upon the transfer of ownership from Union Lumber Company to Georgia-Pacific (GP). Barbara Barnard recalls (personal communication) that at least north and south forks of Wages Creek was completely denuded of trees such that all you could see was clay soil and debris where a dense forest once stood. Wages Creek was heavily logged over the GP ownership again in the 1970s (GP).

Pete Masolini was one of a few farmers on Wages Creek. Michele (his daughter) told me she helped him weed a lot of carrots on the Wages Creek flood plains. He also grew a variety of apples and other vegetables. The Stensgard family a little further up the valley grew potatoes and grazed sheep. Sheep ranching was popular for awhile but 'foot rot' and coyotes killed many animals in a short period of time and few sheep have been raised here since (Barbara Barnard, Ed White personal communications)

Late 1990s: Major land uses in the watershed today are, in decreasing order of magnitude, logging, rural residential living, animal husbandry (pot-bellied pigs, cattle, horses, and chickens), agriculture, and wild mushroom hunting. Marijuana gardens probably exist in the watershed but their locations are not known. Matsutake mushrooms (Armillaria pondersosa) are sought by mushroom hunters in this and other nearby watersheds because of their high export value. While more casual mushroom hunters traverse the hillslopes on foot looking for chanterelles (Cantherellus cibarius), hedgehogs (Dentinum repandum), boletes (Boletus sp) and other edible fungi, it is the matsuke hunters on all-terrain vehicles that disturb vegetation and underlying soil structure.

Natural Setting

1. *Topography*

The topography of the entire Wages Creek basin (Figure 2) includes approximately 13 square miles (8488 acres). About 300 acres are low-lying floodplain at an elevation of approximately 70 feet. The remaining 8188 acres are steeply forested. USGS quadrangles comprising the Wages Creek basin map include Westport, Lincoln Ridge, Inglenook, and Dutchman's Knoll. These were used in the construction all basin maps of Wages Creek.

2. *Geology*

Geologic parent material in the Wages Creek basin is the Franciscan Formation, an assemblage of geologically young, partially fractured sandstone and 'melange'. The weaker melange component, including remnants of volcanic rock, slippery serpentine prone to landsliding, has failed in several upland locations in the watershed, as mapped by air-photo interpretation onto USGS topographic base maps by the California Division of Mines and Geology (Figure 4). Two rotational slides are mapped on the Lincoln Ridge quadrangle and together comprise 120 acres. The 1997 New Years Day flood triggerred several landslides in the watershed, predominately on non-forrested grassy hillslopes.

The floodplain is mapped as alluvium; presumeably weathered, sorted, transported colluvium from the underlying franciscan basement rock. Instream gravels are mostly nickel to quarter sized, even upstream to the forks of Wages Creek.

3. Soils

Soils in the watershed were described in the 2 timber harvest plans I reviewed, written by Georgia-Pacific staff. They are generally deep, well drained, gravelly loams of moderate erosion hazard rating. Forest soils found in the watershed include Dehaven-Hotel, Ombaun-Zeni, Yellowhound-Kibsillah-Ombaun, and Yellowhound-Kibsillah, Irmulco-Tramway #340, and Irmulco-Tramway #343 (THP #1-96-140 MEN). Alluvial soil is termed #221 by the Mendocino County Natural Resource Conservation District. It is river deposited sand and silt (Mendocino County Natural Resource Conservation District).

4. Vegetation

Riparian. Riparian vegetation along the streamside boundary is dominated by Red alder (Alnus rubra) and Willow (Salix sp). Occasional conifers including Coast Redwood (Sequoia sempervirens, Sitka Spruce (Picea sitchensis) , and Hemlock (Tsuga heterophylla) appear in the riparian as well as Bigleaf Maple (Acer macrophyllum). Occasional wild rose is found in remnant patches in the shrub layer along with wild blackberry (Rubus, sp) The forbes layer includes a variety of grasses, fern, mint, and stinging nettle.

Marshes: Marshes are found especially in ephemeral or overflow channels and in lower, wet places in the flood plain meadow of Wages Creek. These marshes incorporate a varying plant community of Bulrushes (Scirpus sp.), Rushes (Juncus sp) sedges (Carex sp.), Spikerush (Eleochorus sp), Blackberry (Rubus sp), Water milfoil (Myriophyllum sp), Water parsley (Oenanthe sp), and Stinging nettle.

Floodplain. By far the majority of floodplain vegetation is a mix of native and introduced grasses (Family Graminae), with inclusions of the marsh habitat described above. In the ecotone dividing the floodplain from the upland, Red alder (Alnus rubra), and willow (Salix sp) are present, usually because the slope angle change functionally collects water providing the similar habitat of a riparian community. Other frequent plants in the ecotone trending to the drier side include Elderberry (Sambucus sp.), Oregon Wild Grape (Berberis aquifolium), Currant (Ribes sp.), and blackberry (Rubus sp.)

Upland. The upland is a mixed coastal redwood montane forest, including Douglas fir (Pseudotsuga menziesii), Grand fir (Abies grandis), Hemlock (Tsuga heterophylla), and Sitka spruce (Picea sitchensis) with large patches of tanoak (Lithocarpus densiflora), and pampas grass in areas of extensive clear-cut logging units left to natural regeneration. Other sub dominant trees and shrubs include Red alder (Alnus rubra), Wax myrtle (Myrica californica), California Bay-laurel (Umbellularia californica), Madrone (Arbutus menziesii), and Cascara (Rhamnus Pursiana). Timberlands are primarily site II (GP). Few "old-growth" trees remain, and those present are located in areas difficult to access by loggers or have significant defect such that their commercial value prohibits the expense required to extract them.

Hydrology

1. Precipitation

Precipitation in Wages Creek is assumed to be equivalent to that recorded at the nearest official California State Water Resources Control Board precipitation gauge. This gauge has been operated by Sally Grigg since June of 1981 near the mouth of Howard Creek, two watersheds north of Wages Creek, at the Howard Creek Ranch approximately 1/4 mile upstream of the mouth of Howard Creek. The water year for this record is July through June. Data and graphs from 1981, for example, includes rain falling from July of 1980 through June of 1981. Average annual rainfall for Wages Creek is 46.6 inches, ranging between 27 and 77 inches, falling almost exclusively as rain from October through May (Figure 5).

Assuming each of the 8488 acres comprising the basin receives 46.6 inches of precipitation annually, 3.88 feet of water per year is received on 8488 acres totalling 32,961 acre-feet per year. This is equivalent to 10,740,613,000 gallons of rain in the course of 1 year (1 acre-foot = 325,851 gallons). Precipitation either evaporates immediately, is intercepted by the soil, or runs off over the ground surface. The proportion or precipitation each of these fates receives is determined by factors which include air temperature, soil type, soil moisture, rainfall intensity, and the degree and type of hillslope vegetation, and the gradient of the hillslope. Once in the soil, moisture may take a variety of paths including plant evapotranspiration, percolation into the groundwater, and adsorption to soil particles (Dunne and Leopold, 1978).

2. Stream Flow

Streamflow is the sum of surface runoff and groundwater discharge distributed over time. A streamflow analysis of the Eel River by Georgia-Pacific revealed that less than 1.5% of the annual streamflow occurrs from August through September (GP SYP p38). Applying this flow regime to Wages Creek, which averaged 7 cfs for these months,100% of annual discharge of Wages Creek at the hwy 1 bridge would come to 28,560 Acre-Ft/yr, the equivalent of 86.6% of average annual precipitation (32,961 acre-feet per year). If 86.6% of annual precipitation discharges from the basin as Wages Creek streamflow, and groundwater recharge = groundwater discharge, then 13.4% of annual precipitation (4608 acre feet or 1,501,599,612 gallons) must be the total of evaporative losses, evapotranspiration by vegetation, and wild/domestic water consumption every year.

The permit authorized by the California Water Resources Control Board limits the total annual diversion of Wages Creek surface water to 47 acre-feet, (0.00164% of the annual surface water flow estimated as 28,560 AF). The predicted annual extraction for the treatment plant in 1995 as given by Barrett & Associates in 1972 was 32.2 Acre-feet per year. In 1994 the actual extraction summed to just 15 acre-feet; just 32% of our maximum permitted outtake, 0.000525% of the annual streamflow estimated at 28,560 AF, or 0.000455% of annual precipitation.

APPENDIX B

SURFACE-WATER QUALITY-ASSURANCE PROJECT PLAN

SURFACE-WATER QUALITY-ASSURANCE PLAN FOR THE SOUTH FORK WAGES CREEK EFFECTIVENESS MONITORING PROJECT

Streamflow and Sediment Transport Monitoring Program – Field and Office

Graham Matthews & Associates

July 2003

Principal Investigator	**Signature**	______________________________
	Name/Date	______________________________
HTC Project Manager	**Signature**	______________________________
	Name/Date	______________________________
CDF Project Manager	**Signature**	______________________________
	Name/Date	______________________________
NCRWQCB Officer	**Signature**	______________________________
	Name/Date	______________________________

SURFACE-WATER QUALITY-ASSURANCE PLAN FOR THE SOUTH FORK WAGES CREEK EFFECTIVENESS MONITORING PROJECT

Abstract
This Surface-Water Quality-Assurance Plan documents the standards, policies, and procedures to be used for activities related to the collection, processing, analysis, storage, and reporting of surface-water data for the South Fork Wages Creek THP Effectiveness Project Monitoring Program.

INTRODUCTION

Surface-water information, including stream-flow, stage, and sediment data, is used for resources planning and management. The purpose of this Surface-Water Quality-Assurance Plan (QA Plan) is to document the standards, policies, and procedures used by GMA for activities related to the collection, processing, storage, and publication of surface-water data for the SF Wages Creek THP Effectiveness Project under a contract to Campbell Timberland Management. Significant portions of this document are based on a QA Plan developed by the California District of the USGS and a previous and more detailed QA Plan developed by GMA for other hydrologic and geomorphic monitoring projects.

This plan identifies responsibilities for ensuring that stated policies and procedures are carried out. The plan also serves as a guide for all GMA personnel involved in surface-water activities and as a resource for identifying publications, and other literature that describe in more detail associated techniques and requirements. The scope of this report includes discussions of the policies and procedures followed by GMA for the collection, processing, analysis, storage, and reporting of surface-water data. Specific types of surface-water data include stage, streamflow, and sediment transport measurements. In addition, issues related to the management of the computer database and employee safety and training are presented.

RESPONSIBILITIES

Quality assurance (QA) is an active process. Achieving and maintaining high-quality standards for surface-water data are accomplished by specific actions carried out by specific persons. Errors and deficiencies can result when individuals fail to carry out their responsibilities. Clear and specific statements of responsibilities promote an understanding of each person's duties in the overall process of assuring surface-water data quality. The following is a list of responsibilities of GMA personnel involved in the collection, processing, analysis, storage, or publication of surface-water data.

The Prinicipal Investigator (PI) is responsible for:

1. Managing and directing the GMA program, including all surface-water activities.
2. Ensuring that surface-water monitoring activities conducted by GMA meet the needs of its clients including, the Federal government, State and local agencies, other cooperating agencies, and the general public.
3. Ensuring that all aspects of this QA Plan are understood and followed by GMA personnel. This is accomplished by the GMA PI’s direct involvement or through clearly stated delegation of this responsibility to other personnel in GMA.
4. Performing technical reviews of all surface-water programs on a regular basis.
5. Ensuring that all reports and other technical communications released by GMA are accurate and are in accord with GMA policy.

The Project Manager (PM) is responsible for:

1. Designing data-collection activities in the field area.
2. Assuring the accuracy of the gaging station records.
3. Providing leadership for staff members.
4. Maintaining expertise in all phases of data-collection, compilation, and computation.
5. Providing on-the-job training (OJT) and formal training for subordinates.

The Staff Hydrologist (SH) is responsible for:

1. Correctly and accurately making discharge measurements of various types.
2. Installing, servicing, and repairing gaging station instruments.
3. Entering data retrieved from gaging station instruments into the WHS data base.
4. Developing ratings and entering them into WHS.
5. Computing discharge records and writing station descriptions and analyses.
6. Helping construct gaging facilities.

COLLECTION OF STAGE AND STREAMFLOW DATA

Reliable surface-water data are necessary for planning and resource management. The collection of stage and streamflow data is a primary component in the ongoing operation of streamflow-gaging stations (referred to in the remainder of this report as gaging stations) and other water-resource studies performed by GMA.

The objective of operating a gaging station is to obtain a continuous record of stage and discharge at the site (Carter and Davidian, 1968, p. 1). A continuous record of stage is obtained by installing instruments that sense and record water-surface elevation in the stream. Discharge measurements are made at periodic intervals to define or verify the stage-discharge relation and to define the time and magnitude of variations in that relation.

It is the policy of GMA that all personnel involved in the collection of stage and discharge data shall be properly trained, well informed, and follow the surface-water data collection policies and procedures established by GMA.

Gage Installation and Maintenance

Proper installation and maintenance of gaging stations are critical activities for ensuring quality in streamflow data collection and analysis. Effective site selection, correct design and construction, and regular maintenance of a gage can make the difference between efficient and accurate determination of discharge or time-consuming, poor estimations of flow. Sites for installation of gaging stations are selected to meet specific data-collection needs. Additionally, sites should have, to the greatest extent possible, ideal hydraulic conditions. The individual responsible for selecting sites for new gaging stations is the PI or PM.

Measurement of Stage

It is GMA policy that surface-water stage records at stream sites be collected with instruments and procedures that provide sufficient accuracy to support computation of discharge from a stage-discharge relation, given the budgetary constraints of such a program.

In general, operation of gaging stations for the purpose of determining daily discharge includes the goal of collecting stage data at the accuracy of + or - 0.01foot. The types of instrumentation installed at all continuous gaging sites for the SF Wages Creek THP Effectiveness Monitoring Project are Design Analysis H-310 pressure transducers wired to Campbell Scientific CR510 dataloggers. Ensuring that new equipment has been installed correctly is the responsibility of the

PM. Proper maintenance of gage instrumentation or replacement, if appropriate, of equipment is the responsibility of field personnel who service the gage.

Accurate stage measurement requires not only accurate instrumentation but also proper installation and continual monitoring of all system components to ensure the accuracy does not deteriorate with time.

At pressure transducer installations, the reference gage will be a sturdy low-water section of outside staff gage near the orifice. The principal gage will be the readout for the transducer. Generally, the instrument should be reset to the reference gage only when the stage in the stream is low and there is no wind or wave action, and there is minimal pile-up or drawdown around the reference gage. At high stages, the instruments usually are a more reliable index of gage height than the upper staff readings. Significant gage-height differences can be corrected later with datum adjustments if analysis shows that the instrument was truly in error.

Gage Documents
It is GMA policy that certain documents are maintained with the SH for the purpose of keeping a record of observations, equipment maintenance, structural maintenance, and other information helpful to field personnel. Documents maintained by the SH for each gaging station include: (1) the most recent digital stage-discharge relation (rating table); (2) a graph of the rating upon which each new measurement is plotted; and (3) a list of discharge and CSG measurements for each site. It is the responsibility of personnel, who run a field trip regularly, to maintain updated forms for each gaging station.

Levels
The various gages at a gaging station are set to register the height of a water surface above a selected level reference surface called the gage datum. Levels are run periodically to all bench marks, reference marks, reference points, and gages at each station for the purpose of determining if any datum changes have occurred (Rantz and others, 1982, p. 545).

Photographs
Photographs of newly installed gages, station controls, possible indirect measurement sites, reference marks, and damaged structures are made by field personnel for the purpose of documenting gage construction, changes in control conditions, or to supplement various forms of written descriptions. Digital cameras are made available by the PM as needed. Each digital photograph that becomes part of the station record is identified by using a file naming convention that includes station name and date. Digital photographs are placed in station digital files.

Site Documentation
Thorough documentation of qualitative and quantitative information describing each gaging station is required. This documentation, in the form of a station description and photographs, provides a permanent historic record of site characteristics, structures, equipment, instrumentation, altitudes, location, and changes in conditions at each site. Information pertaining to where these forms of documentation are maintained is discussed in the section of this report entitled “Office Setting.” A station description is prepared for each gaging station, water quality, or sediment data-collection site and becomes part of the permanent record for each station. The responsibility for ensuring that station descriptions are prepared correctly and in a timely manner is held by the PM.

Station Descriptions
It is the responsibility of the PM to ensure that station descriptions are updated. Descriptions are reviewed and updated by the responsible field person. Station descriptions are written to include specific types of information in a consistent format (Kennedy, 1983, p. 2).

Direct Measurements

Direct measurements of discharge are made with any one of a number of methods used by GMA. The most common is the current-meter method. A current-meter measurement is the summation of the products of the subsection areas of the stream cross-section and their respective average velocities (Rantz and others, 1982, p. 80). Procedures used for current-meter measurements are described by Rantz and others, 1982, p. 139; Carter and Davidian, 1968, p. 7; and Buchanan and Somers, 1969, p. 1. When personnel make measurements of stream discharge, attempts are made to minimize errors. Sources of errors are identified by Sauer and Meyer, 1992. These include random errors such as depth errors associated with soft, uneven, or mobile streambeds, or uncertainties in mean velocity associated with vertical-velocity distribution errors and pulsation errors. These errors also include systematic errors, or bias, associated with improperly calibrated equipment or the improper use of such equipment. To minimize systematic errors, field equipment is typically rotated to different personnel throughout the water year.

Exchange of current meters among field personnel is expected for each trip or on a specified, regular basis. The idea is to eliminate the possibility of one group of station records being biased by a meter that deviated from the standard meter rating. The exchange has an additional advantage in that it may raise the general level of meter maintenance. The PM assigns a specific SH to manage the exchange of meters. A chronological log of meter maintenance and exchange is maintained. GMA policies related to the measurement of discharge by use of the current-meter method are in accordance with standard USGS policies. No other discharge methods beyond the current meter method will be used in this project, unless extremely high flows occur during the project time period and subsequent slope-area measurements of peak flows are made.

Field Notes

Thorough documentation of field observations and data-collection activities performed by field personnel is a necessary component of surface-water data-collection and analysis. To ensure that clear, thorough, and systematic notations are made during field observations, discharge measurements are recorded by field personnel on standard GMA discharge-measurement forms and are summarized in field books as a backup.

Measurement Checking

Each trained person making discharge measurements is solely responsible for completely and accurately filling out the GMA Discharge Measurement sheet and the computational accuracy of the measurement, although this is usually done by the Aquacalc 5000, stream discharge computer.

1. Immediately upon completion of a measurement computation, each person is expected to:
   a. Scan the measurement for obvious errors in velocity, depth, partial areas, partial discharges.
   b. Scan for misplaced decimal points.
   c. Check the sum of partial widths against total width.
   d. Recompute the sum of partial areas and discharges.
3. If a measurement is more than 10 percent off the existing trend when compared to the rating, a check of that measurement is required.

Acceptable Equipment

Equipment used by GMA for the measurement of surface-water discharge has been found acceptable by the USGS through use and testing. An array of acceptable equipment for measuring discharge includes current meters, timers, wading rods, bridge cranes, tag lines, and others (Rantz and others, 1982, p. 82; and Smoot and Novak, 1968). Although an official list of acceptable equipment is not available, Buchanan and Somers (1969), Carter and Davidian (1968), and Edwards and Glysson (1988) discuss the equipment used by the U.S.Geological Survey.

The meters most commonly used by GMA personnel for measuring surface-water discharge are the Price AA current meter and the Price pygmy current meter. Methods followed by GMA personnel for inspecting, repairing, and cleaning these meters are described by Smoot and Novak (1968, p. 9), Rantz and others (1982, p. 93), and Buchanan and Somers (1969, p. 7). The ultimate responsibility for the good condition and accuracy of a current meter rests with the field person who uses it. A timed spin test made a few minutes before a measurement does not ensure that the meter will not become damaged or fouled during the measurement. Field personnel must assess apparent changes in velocity or visually inspect the meter periodically during the measurement to ensure that the meter continues to remain in proper operating condition.

Spin tests.--It is GMA policy that spin tests are required prior to each field trip. Spin-test results are documented in a log that is maintained for each instrument. The log is located in the project office. Repairs are made to meters when deficiencies are identified through the spin test or inspection. Review of this log by the PM is made annually. If deficiencies are observed during this review of the log, the field person responsible is informed and the problem is corrected immediately.

Crest-Stage Gages
Crest-stage gages are used as tools by GMA for determining peak stages at otherwise ungaged sites, confirming peak stages where pressure transducers are used, and determining peak stages along selected stream reaches or other locations, such as upstream and downstream from bridges and culverts. GMA requires quality-assurance procedures comparable to those used at continuous-record stations for the operation of crest-stage gages and for the computation of annual peaks at crest-stage gages.

The operation of crest-stage gages is part of GMA's surface-water program. Procedures followed by GMA in the operation of crest-stage gages are presented by Rantz and others (1982, p. 9, 77, 78). One or more gages are maintained at each selected site where peak water-surface elevations are required on a stream. Upstream and downstream gages are maintained at culverts or other structures where water surface elevations are required to compute flow through the structure and to establish the resulting type of flow. Except at sites where crest-stage gages are used only to confirm or determine peak stages, stage-discharge relations are developed in association with the gage based on direct or indirect high-water measurements. Field observations are written on standard field forms. All field notes are required to include: initials and last name of field person, date, time of observation, gage height(s), outside high-water marks, and condition of control.

PROCESSING AND ANALYSIS OF STREAMFLOW DATA

The computation of streamflow records involves the analysis of field observations and field measurements, the determination of stage-discharge relations, adjustment and application of those relations, and systematic documentation of the methods and decisions that were applied. Streamflow records are computed and reported for each gaging station annually (Rantz and others, 1982, p. 544).
This section of the QA Plan includes descriptions of procedures and policies pertaining to the processing and analysis of data associated with the computation of streamflow records. The procedures followed by GMA coincide with those described by Rantz and others (1982) and by Kennedy (1983).

Measurements and Field Notes
The gage-height information, discharge information, control conditions, and other field observations written by personnel onto the measurement note sheets and other field note sheets form the basis for records computation for each gaging station.

Measurements and other field notes for the water year that is currently being computed are filed in the current record folder. After the measurement data are entered into computer files by use of Excel software, then a paper printout of that information may be filed. Original data obtained by direct observation in the field is called "observed data" ; subsequent values derived from the observed data are called "computed data." The distinction between observed data and computed data is that observed data cannot be recovered if lost; computed data can always be recovered from the observed data. Therefore, observed data should never be altered or destroyed. The same basic principles can be applied to sediment, water quality, and ground water field notes, level and survey notes, and the observations recorded on charts or tapes.

Measurement Summary List (9-207)
The GMA Discharge Measurement listing will be the official final documentation to accompany the station record and, as such, must be complete and accurate. The GMA form is printed and filed with the final record.

Continuous Record
Surface-water gage-height data are collected as continuous record (typically hourly, 30-minute, or 15-minute values) in the form of electronic storage by data loggers. Streamflow records are computed by converting gage-height record to discharge record through application of stage-discharge relations. Ensuring the accuracy of gage-height record is, therefore, a necessary component of ensuring the accuracy of computed discharges. Gage-height record is assembled for the period of analysis as completely as possible. Periods of inaccurate gage-height data are identified, corrected (see the section "Datum corrections, gage-height corrections, and shifts"), or deleted as appropriate. Items included in the assembly of gage-height record and procedures for processing the data are discussed by Kennedy (1983, p. 6) and Rantz and others (1982, p. 560 and p. 587).

Records and Computation
Records computed for a given station are often completed by a single individual for the entire hydrologic year. . A SH who has demonstrated proficiency in stream gaging record computation should not require a 100-percent check on work produced. All records receive a summary review by the PM. Approximately 10 percent of all records are reviewed in detail by the PM or PI.

Procedures for Working and Checking Records
Procedures for ensuring the thoroughness, consistency, and accuracy of streamflow records are described in this section. The goals, procedures, and policies presented in this section are *grouped in association with the separate components that are included in the records-computation process.* Quality standards should be tempered by practical considerations of time and money resources. This applies only to revisions based on interpretations, and not to corrections of unquestionable errors. True errors are corrected regardless of their magnitude. When reviewing surface-water records, daily discharges do not have to be revised unless the day in question would be changed by more than 10 percent, or if the monthly mean would be changed by 5 percent or more.

Gage Height
The accuracy of surface-water discharge records depends on the accuracy of discharge measurement, the accuracy of rating definition, and the completeness and accuracy of the gage-height record. Computation of streamflow records includes ensuring the accuracy of gage-height record by comparisons of gage-height readings made by use of independent reference gages, comparison of inside and outside gages, examination of high-water marks, comparisons of the redundant recordings of peaks and troughs by use of maximum and minimum indicators, examination of data obtained at crest stage gages, and confirmation or updating of gage datums by levels. Records computation includes examination of gage-height record to determine if the record

accurately represents the water level of the body of water being monitored. Additionally, it includes identifying periods of time during which inaccuracies have occurred and determining the cause for those inaccuracies. When possible and appropriate, inaccurate gage-height record is corrected. When corrections are not possible, the erroneous gage-height data are removed from the set of data used for streamflow records computation.

Gage Height Records and Time Changes
All electronic recorders are set to Pacific Standard Time. This requirement affects all Electronic Dataloggers (EDL) and all data-collection Platforms (DCP).

Ratings
The development of the stage-discharge relation, also called the rating, is one of the principal tasks in computing discharge record. The rating is usually the relation between gage height and discharge (simple rating). GMA personnel follow procedures for the development, modification, and application of ratings that are described by Kennedy (1984). GMA personnel also follow guidelines pertaining to rating and records computation that are presented by Kennedy (1983, p. 14) and by Rantz and others (1982, Chap. 10-14 and p. 549). For each gaging station, the most recent digital rating table can be obtained from a computer file. A graphical plot of the most recent rating can be obtained from file folders (original hand-drawn curve), or from computer files sent to an output device. The PM is ultimately responsible for ensuring that ratings are correctly developed, entered into the computer, checked, and stored.

Station Analysis
A complete analysis of data collected, procedures used in processing the data, and the logic upon which the computations were based is documented for each year of record for each station to provide a basis for review and to serve as a reference in case questions arise about the records at some future date (Rantz and others, 1982, p. 580). Topics discussed in detail in the station analysis include equipment, hydrologic conditions, gage-height record, datum corrections, shifts, rating, discharge, special computations, remarks, and recommendations, (Rantz and others 1982, p. 582 and Kennedy 1983, p. 46). The station analysis is written by the individual who prepares the final update for the water year. Individuals who produce portions of the computations for the year should write sections of the station analysis pertaining to the work they completed. The quality control person is expected to discuss changes or corrections with the individual who summarized the records. The PM holds the responsibility for resolving disputes. The record worker has the responsibility for ensuring that station analyses are prepared using the approved format. The PM is responsible for ensuring that an updated version resides in the correct computer directory.

Review of Records
In preparing the annual data report for publication, GMA follows the guidelines presented in the report, “WRD Data Reports Preparation Guide,” by Charles E. Novak, 1985 edition. To ensure that correct surface-water information is presented in the annual report, each report page is reviewed by the PM. Findings of the review are presented to the record worker orally. The record worker is responsible for correcting deficiencies and documenting corrective actions.

GMA Check List
GMA maintains a record of progress on discharge computation for each gaging station. GMA finds it helpful to have a checklist for each station for each water year. This checklist is a means of tracking the status of records computation for each station and ensuring that errors do not occur by omitting the necessary procedural steps. The checklist is filed with the primary computations during the year. There is no need to maintain the completed checklist after discharge records for each station have been finalized.

COLLECTION OF WATER QUALITY DATA

Reliable surface-water water quality data are necessary for planning and resource management. The collection of water quality data is sometimes a primary component in the ongoing operation of gaging stations and other water-resource studies performed by GMA.

The objective of collecting water quality data within the SF Wages Creek THP Effectiveness Monitoring Project area is to produce reliable records of turbidity using the Redwood Sciences Lab TTS Protocol to compare pre-and post-project conditions.

It is the policy of GMA that all personnel involved in the collection of physical water quality data shall be properly trained, well informed, and follow the surface-water data collection policies and procedures established by GMA.

Sampling Procedures

Field water quality parameters to sample include water temperature and turbidity. Water temparture will be measured with a Campbell thermistor, while turbidity will be measured with an FTS DTS-12 turbidity probe. Both units will log data to a Campbell Scientific CR10X datalogger. Data will be downloaded into a PC and compiled by the GMA. A laptop computer will be used for downloading data.

Parameter	Bottle Type	Matrix	Sample Preservation	Holding Time
Turbidity	1000 ml	aqueous	NA	48 hrs
Turbidity	Real time	aqueous	NA	NA
Temperature	Real time	aqueous	NA	NA

Calibration Procedures and Frequency

All calibrations will follow manufacturers instructions and those developed for the TTS protocols. The calibrations will be recorded on a field calibration sheet, which will be filed in a project notebook. Field personnel will have been trained to properly calibrate the sensors. All calibration solutions are purchased from the manufacturer. GMA staff will conduct periodic recalibration of the instruments using proper solutions. For the first few months the instruments probes will be checked every two weeks to ensure proper calibrations, then each probe will be assigned a schedule for a calibration check based on frequency and drift previously observed.

Troubleshooting Procedures

When a sensor cannot be calibrated with standard solutions, the SH must determine if the problem resides with the monitoring sensor or with the monitor itself and make necessary corrections to ensure that the monitor is operational. The SH will carry spare sensors in the field so that troubleshooting, if necessary, can be accomplished at the time of the service visit. Troubleshooting in the field can prevent the need for extra trips, and greatly reduce lost records and the amount of time spent in processing the records in the office later. A successful service trip results in a properly calibrated and operating monitoring sensor.

Field Notes and Instrument Logs
Field notes and instrument logs are the basis for the accurate and verifiable computation of water quality monitoring records. Minimum requirements in the field notes for water-quality monitors include the following items:

• Station number and name
• Name(s) of data collector(s)
• Date and times of each set of measurements
• Field meter and monitor serial numbers
• Purpose of the site visit
• Horizontal and vertical locations of sensors in the cross section (if applicable)
• Recorded monitor values and corresponding field values (initial, after cleaning, and final instream readings)
• Cross-section measurement data (locations of verticals, constituent values, and measurement time)
• Cross-section measurement summaries and corrections
• Pertinent gage-height data
• Remarks that describe channel conditions, condition of the sensors, and so forth
• Battery voltage of monitor at arrival and departure (and whether replacement occurred)
• Documentation of sensor replacement (and other remarks or observations that may aid in further processing of the record)

Forms including these items encourage consistency and help to avoid the costly omission of critical information. GMA uses a field form, based on USGS version that constitutes a comprehensive checklist for data collection at many water-quality monitoring sites. Each field meter and water-quality monitor has an instrument logbook, and all pertinent information regarding the monitor is recorded in the instrument logbook. One of the most significant pieces of recorded information is the instrument calibration—both field and laboratory. Calibration information can be recorded initially on field forms or field notebooks, but the information then must be copied into the instrument logbook. The instrument logbook should contain a complete record of all maintenance in the field, the laboratory, or by the manufacturer. Permanent instrument logs contain critical calibration and maintenance information that document instrument performance throughout the useful service life of the instrument. Calibration log information that is important from a record-processing standpoint includes:

• Calibration dates, times, and temperatures
• Calibration standard values and lot numbers
• Initial and final monitor calibration data
• Field meter calibration values

Field notes and calibration log information will be clearly written, and all notations should be self-explanatory. The goal is to have sufficient information for another individual to complete the record processing steps, if necessary. Clear notes simplify the record check and review processes.

PROCESSING AND ANALYSIS OF PHYSICAL WATER QUALITY DATA

Processing and analysis of physical water quality data involves the analysis of field observations and field measurements, adjustment of those data based on calibration data, and systematic documentation of the methods and decisions that were applied. Water quality data are reported for each gaging station annually.

This section of the QA Plan includes descriptions of procedures and policies pertaining to the processing and analysis of water quality data.

Data-Processing Procedures

The processing of water-quality monitoring records will be completed in a timely manner according to water-quality-assurance plan policies. Complete and accurate field notes are an important part of the data processing and reduce the amount of time required to process the data. Corrections to data should not be made unless the causes of errors can be validated or explained by notes or by comparison to information from adjacent stations. Data processing can be classified in six major categories: (1) initial data evaluation, (2) application of corrections and shifts, (3) application and evaluation of cross-section corrections, (4) final data evaluation, (5) record checking, and (6) record review.

Initial Data Evaluation

The initial data evaluation checks the success of the transfer of raw field data (instrument readings) to the office data base and provides the opportunity for initial checks to evaluate and correct erroneous data (daily, if telemetry is available). Raw field data may be stored in a variety of formats, depending on the recording equipment and the means of downloading data from the recording equipment. The conversion of raw data from a variety of recording devices into a standard entry format to the GMA Project data base generally is accomplished with the use of standard software. Sensors, recorders, transmitters, receivers, relays, transmission systems, or unforeseen events can, at times, produce unexplainable data. Data should be reviewed daily, if possible, to edit obviously erroneous data caused by data transmission problems. Data should be processed immediately after the service visit and viewed graphically. In addition to confirming the accurate transfer of data, this may aid in detecting instrument or sensor errors. Data that are missing (for example, because of instrument or transmission problems) should not be estimated, but missing data should be documented and no statistics should be calculated that involve missing data.

Application of Corrections and Shifts

The application of corrections and shifts allows data to be adjusted to compensate for errors that occurred during the service interval as a result of environmental or instrumentation effects. Three types of measurement-error corrections are described here—fouling, drift, and cross-section correction. Corrections only should be made to measurements when the type and degree of correction is known. The sequence for determining the type and degree of measurement error in the field and the application of corrections is fouling, drift, and cross-section correction. If the deviation between actual value and sensor reading exceed the criterion for water-quality data shifts (table 1), a correction is required. The correction is a linear interpolation over the time between sensor inspections.

The same measurement criteria used to determine the need for calibration are used to determine the need for water-quality data shifts. In general, shifts are required when the deviation between actual and recorded data exceed the shift criteria listed in table 1. Decisions for data shifts and corrections will be resolved by the SH and the GMA QA/QC team.

Table 1. Criteria for water-quality data shifts [+, plus or minus value shown; ºC, degree Celsius; NTU, nephelometric turbidity unit]

Measured physical property shift criteria (apply shift when deviation exceeds this value)	
• Temperature (may	+ 0.2 ºC
• Turbidity	The greater of + 2 NTU or + 5 percent of the measured value

Fouling
Fouling may result from several sources and also may be event-related. Identification of electronic drift or loss of sensor sensitivity should be distinguished from fouling drift, if at all possible. The degree of fouling is determined from the difference between sensor measurements before and after the sensors are cleaned. Modern temperature sensors are sturdy, dependable, and resistant to fouling. Turbidity sensors can be affected by fouling problems when mineralization, severe sedimentation (for example, during the recession period of a flood), or aquatic algal growth occurs. In general, the FTS sensors with wipers have been shown to provide excellent service and are sturdy, easy to clean, and the calibrated field meters are reliable.

Continuous records of turbidity are often the most difficult to maintain within acceptable limits for accuracy and precision. Because of this, the time period between service visits may need to be shortened to maintain the quantity and quality of the turbidity record. Sensor fouling, as a result of biological or chemical particles accumulating on the sensors, can occur on any monitor left in the stream for a period of time. Although fouling frequently begins as soon as the monitor is placed in the stream for deployment, a rise in gage height generally will contribute more to fouling overall. If a turbidity probe is equipped with wiper or shutter technology and is properly maintained, the need for a fouling correction will be minimized. The optic mechanism on the turbidity sensor is extremely sensitive to build up; if the probe is not equipped with wiper or shutter technology, accuracy of turbidity data will be impaired significantly. A fouling shift generally is applied as a datum correction from either the last time the sensor was cleaned, from the last rise in gage height, or from a significant event noted in the field notes.

Drift
A calibration drift is an electronic drift in the equipment from the last time it was calibrated and is determined by the difference between readings of a cleaned sensor in standards or buffers and a calibrated sensor. If, after checking, the deviation from calibrations is within the calibration criteria of the sensor, then no sensor drift is present. Drift is assumed to occur at a constant rate across the service interval. If the sensor readings exceed the shift criteria (table 1), then the correction is a linear interpolation over the time between calibration checks. This is called a prorated shift. Corrections to the record can be applied as a 3-point variable shift in the project database. This value-dependent adjustment is called a variable shift and is applied in situations where standards at the beginning and ending of the service interval have different amounts of deviation (variable shifts). Variable shifts can be accomplished for any parameter, and this is the recommended technique for corrections related to instrument drift. Because three standards frequently are used for monitor calibration, the variable shift is the preferred method of correction for drift. The treatment for suspected sensitivity loss is sensor reconditioning or replacement.

Evaluation and Application of Cross-Section Corrections
The purpose of cross-section corrections is to adjust the measurements of the monitoring equipment to reflect conditions more accurately in the entire stream cross section, from bank to bank and surface to bottom. The principal value of such adjusted measurements is realized when concurrent discharge measurements permit the computations of constituent loads transported past the station. The application of cross-section corrections is intended to improve the accuracy and representativeness of monitoring measurements; however, cross-section corrections should be made only if the variability in the cross section exceeds the shift criteria. Corrections to the cross section are based on field measurements taken both horizontally and vertically in the stream cross section. Specific corrections for temperature and turbidity are made, since they may differ from each other at each site, and they all are site dependent and may be discharge and seasonally dependent as well. Several considerations govern the use of corrections. Cross section measurements must be made under a variety of flow conditions (minimum of six), all seasonal

conditions, and at least twice annually to confirm that the correction being applied to the water-quality measurements truly represents the median or mean cross-section values. Corrections should not be applied to water-quality measurements beyond the range of discharge measurements nor during periods of unsteady flow. If the correction for a measured physical property is consistent across a range of discharges and seasons, then correction of the measurement values by simple adjustment is warranted. Seasonal changes in water quality may be representative of the hydrologic system, but they also may be a result of local conditions. Professional judgment and observations in the field logs will assist in evaluating the need for the application of cross-section corrections. Continuous water-quality monitoring has great value in recognizing the interdependence of water-quality physical properties under varying flow regimes. Understanding these relations is essential in the appropriate application of discharge-dependent corrections.

Final Data Evaluation
Final data evaluation consists of reviewing the data record, checking shifts, and making any needed final corrections. When completed, the data are verified for publication and then rated for quality.

COLLECTION OF SEDIMENT DATA

Reliable surface-water data are necessary for planning and resource management. The collection of sediment data is often a primary component in the ongoing operation of streamflow-gaging stations and other water-resource studies performed by GMA, and is critical to the South Fork Wages Creek THP Effectiveness Monitoring Project.

The objective of collecting sediment data at a monitoring site is to allow computation of sediment transport loads. Sediment loads are obtained by combining streamflow records with sediment discharge rating curves. Methods for developing streamflow records have been described in other sections of this report.

Turbidity Controlled Sampling
For estimating suspended sediment concentration (SSC) in rivers, turbidity has been demonstrated to be a much better predictor than water discharge. Since about 1990, it has been feasible to automatically collect high frequency turbidity data at remote sites using battery-powered turbidity probes that are properly mounted in the river or stream. A few (less than 10) data pairs spanning the range of concentrations should be sufficient to reliably establish the relation between SSC and turbidity during such events (Lewis 1996). This relationship provides a means for accurately estimating suspended sediment loads during storm runoff events.

For estimating monthly or annual sediment loads, the relation between SSC and turbidity will vary over time with changes in sediment sources, organic loading, or sensor calibration. Thus, the use of a single curve describing the long-term mean relation will yield greater errors than for short-event (e.g., storm) estimation. Nevertheless, turbidity is generally considered more useful than water discharge as a long-term predictor of SSC. If the turbidity-SSC relation is roughly linear, load estimates will be nearly unbiased. The Redwood Sciences Laboratory (USDA Forest Service, Pacific Southwest Research Station) has been experimenting with various approaches to estimating suspended sediment loads in small streams. They have developed a prototype system where a data logger program employs nephelometric turbidity to make SSC sampling decisions (i.e., to activate a pumping sampler) in real time (Lewis, 1996; Lewis and Eads, 1996). The algorithm uses a separate rising and falling series of threshold turbidity values. A falling condition is detected when turbidity drops a given percentage below the previous maximum, and a rising condition is detected when turbidity rises a given percentage above the prior minimum. Because the falling condition is usually much longer than the rising condition, the falling series has more thresholds. SSC specimens are collected whenever a threshold for the current condition is crossed. Additional constraints are imposed to limit sampling when turbidity is spiking or fluctuating rapidly.

This project will utilize the Turbidity Threshold Sampling (TTS) protocol at four sample sites within the project area. Additional manual stations will collect non-automated data on sediment at tributaries and along the mainstem of South Fork Wages Creek to aid in evaluation of point sources, either along the creek or from tributaries.

Turbidity threshold sampling collects physical samples that are distributed over a range of rising and falling concentrations (see Lewis and Eads: 1996 1998, and 2001). The resulting set of samples can be used to accurately determine suspended sediment loads by establishing a relationship between sediment concentration and turbidity for any sampled period and applying it to the continuous turbidity data. A comprehensive operations manual for a TTS station has been developed by the Redwood Sciences Laboratory (Johnston et al. 2001) and the specific operational steps will not be repeated in this QA Plan. Standard depth-integrated cross stream samples (DIS) are collected during storms to adjust point (TTS pump samples) values to the entire cross section. Procedures for the collection of DIS samples, whether at TTS sites or at manual sites, are described in the following section.

Suspended Sediment Data Collection

Sites will be established prior to planned storm sampling, with site selection considerations based on access, local hydraulics, and high-flow sampling access. If possible, have a fiberglass tape left at sampling section so that the same stations are used each time, or section pins may also be left in place.

1. Upon arriving at site, record gage height and time (24hr clock).

2. Determine if it is safe to collect a depth-integrated sample (DIS) or only a grab sample.

3. Attach extension handles to a DH-48 sampler as necessary to collect a DIS. Fit a pint bottle into the sampler and make sure it is properly seated and that nozzle is not clogged.

4. Divide the stream into 10-20 verticals for DIS, EWI (Equal Width Increment) method, sampling at stations marked on the tape, if possible. Lower the sampler vertically into the flow at a uniform rate, reversing immediately upon touching bottom. Raise the sampler at the same rate as lowering. Move to the next vertical and repeat. Continue across the entire width of the wetted channel. The spacing between all verticals is uniform across the entire channel.

5. If a grab sample is being taken, wade or lean as far out as is safe, dip the sampler into the flow and try to integrate one or more verticals as far out as can be reached with the sampler and extensions.

6. The sample bottle must be 60-90% full after a complete pass. If the sample bottle is more than 90% full, discard sample, rinse bottle, and collect another sample at a slightly faster rate. If the sample bottle is less than 60% full, repeat the sample collection (another full cross section) at a rate that will not overfill the sample bottle. One may also use a second bottle or even multiple bottles to collect a single cross channel sample. Sample bottles will be composited in the lab.

7. Remove the sample bottle. Tightly cap the sample bottle. Store the sample in an ice chest or refrigerator until it is transferred to a lab for processing.

8. Record the following information for each sample: Date, Time, Site, Gage Height, Sampler used (DH-48, DH-59, D-74), sample type (DIS or grab), # of verticals sampled, stations sampled if tape is available, Bottle #, # of bottles (if multiple bottles are used), and any general notes as to weather, unusual site conditions, etc.

9. Every 10 samples, a second pass at the same site should be made (10% of the samples will have a replicate) using identical stations or procedures. The purpose of the replicate is for Quality Control documentation. In addition, at high discharges, much more frequent replicates are made, as the variability of the sample concentrations is greater.

PROCESSING AND ANALYSIS OF SEDIMENT DATA

The computation of sediment records involves the analysis of field observations and field measurements, the determination of discharge-sediment relations, adjustment and application of those relations, and systematic documentation of the methods and decisions that were applied. Sediment transport records are computed and reported for each monitoring site where sediment data are collected.

This section of the QA Plan includes descriptions of procedures and policies pertaining to the processing and analysis of data associated with the computation of sediment records. The procedures followed by GMA generally coincide with those described by Guy and Norman (1970) and by Edwards and Glysson (1988).

Measurements and Field Notes

The gage-height information, discharge information, control conditions, and other field observations written by personnel into field books and other field note sheets form the basis for records computation for each monitoring site.

Sediment Measurement Summary List (SS 9-207)

The GMA Sediment Measurement List will be the official final documentation to accompany the station record and, as such, must be complete and accurate. Print out the GMA form and file it with the final record.

Ratings

At TTS sites, the development of the turbidity-suspended sediment concentration relation, also called the T-SSC rating, is one of the principal tasks in computing sediment records. The sediment rating is usually the relation between discharge and suspended sediment load (simple rating). Ratings for some sites involve additional factors such as rising and falling limb differentiation (complex ratings).

GMA personnel follow procedures for the development, modification, and application of ratings that are described by Porterfield (1972), as modified for the TTS method by the Redwood Sciences Laboratory.

Development of Continuous Suspended Sediment Records

Application of the turbidity-suspended sediment concentration relation to the continuous turbidity record produces suspended sediment concentrations on a 15-minute time step. The values of concentration at each time step are then converted to sediment load by application of the formula: Load = SSC (mg/l) * Q (cfs) * .0027. Values are summed and averaged for mean daily values and totaled for annual values.

OFFICE SETTING

The PM is responsible for maintaining surface-water data and related information in a systematic and organized manner. This increases the efficiency and effectiveness of data-analysis and data-dissemination efforts. Good organization of files reduces the likelihood of misplaced nformation. Misplaced data and field notes can lead to analyses based on inadequate information, with a possible decrease in the quality of analytical results.

Work Plan

Because the type of work and the amount of work varies from project to project, the manner in which a work plan is prepared also tends to vary. Duties are assigned and communicated to personnel by the PI or PM in most cases. This is an informal system where duties are assigned verbally throughout the year. Individuals are assigned stations for which they are accountable by certain deadlines.

Station Descriptions

Permanent copies of the surface-water station descriptions are maintained as computer files. A copy is kept in the current file folder. Individuals are expected to make updates in the computer files (which are available to everyone) whenever there is a significant change or every three years. The PM is responsible for ensuring that files are updated. (A list of files, sorted by year of update, may be obtained on request).

Archiving

All GMA personnel are required to safeguard all original field records containing hydrologic measurements and observations. Selected material not maintained in field offices are placed in archival storage. Detailed information on what records have been removed to archives are retained in the GMA office. The types of original data that should be archived include, but are not limited to, original data and edited data, observer's notes and readings, station descriptions, analyses, and other supporting information (Hubbard 1992, p. 12).

REPORTING OF SURFACE-WATER DATA

All data, including surface-water and sediment data collected for this project will be published in an Annual Data Report. The objective of this instruction is to make sure that all data collected are made available to the public. In general, any measurements made or samples collected and analyzed following GMA approved procedures are considered reportable data.

SAFETY

Performing work activities in a manner that ensures the safety of personnel and others is of the highest priority for GMA. Beyond the obvious negative impact unsafe conditions can have on personnel, such as accidents and personal injuries, they also can have a direct effect on the quality of surface-water data and data analysis. For example, errors may be made when an individual's attention to detail is compromised when dangerous conditions create distractions. So that personnel are aware of, and follow, established procedures and policies that promote all aspects of safety, GMA communicates information and directives related to safety to all personnel by in-house training classes, memorandums, and email. It is the responsibility of each employee to remain current on First Aid and CPR certification. Each employee is expected to read the GMA Safety Handbook.

An individual has been designated as Safety Officer by the GMA. Personnel who have questions or concerns pertaining to safety or who have suggestions for improving some aspects of safety, may direct those questions, concerns, and suggestions to their supervisor, the mentioned Safety Officer, or any senior GMA personnel.

GMA has developed a Safety Program, to be implemented through the following items:

1. Training - GMA will provide ongoing general training, both formally and on the job, along with required training and specific training related to potentially hazardous operations or procedures.
2. Promotion - Safety and health will be promoted by communication and enforcement of safety and health rules and practice.
3. Occupational Hazards and Industrial Hygiene and Inspections - Hazard inspections of buildings, vehicles, and equipment, and duty space to be used by employees will be conducted. Chemical-handling inspections will be completed, and deficiencies will be corrected.
4. Public Safety - All facilities will be maintained and inspected to ensure that the premises are safe for the employees and the public.
5. Accident/Incident Investigations, Reporting and Analysis - Accident and Incidents will be reported and tracked in order to ensure there is no trend, and prevention measures will be sought.

It is the policy of GMA to promote safety and health in our working environment. Because some employees of GMA must perform potentially unsafe duties in the scope of their work, we must establish safety measures to minimize the potential dangers and be constantly aware of those potential dangers. The goal is to create a work environment that is free from injuries or work-related illnesses. To meet this goal, every employee must cooperate in detecting and controlling hazardous and potentially hazardous conditions. Any hazardous situation or practice must be immediately reported in writing to the employee's supervisor and the Safety Officer unless the employee feels that the hazardous condition poses an imminent danger to other employees or the public; then notification should be done by the most expeditious means. No employee shall be subjected to coercion, reprisal, restraint, discrimination, or other adverse actions as a result of reporting hazardous or potentially hazardous conditions. In the work environment, there is always potential for illness and injury. Removal of preventable exposures to illness and injury is of primary importance and should always receive priority consideration over any operation. Management will provide all practical, physical, and educational resources to maintain personal health and safety. All employees must maintain a preventative and cooperative attitude relating to safety issues. Everyone will adhere to all safety-related policies, rules, and procedures and help ensure that any person on our premises or that works with us does the same.

SUMMARY

Information included in this GMA Surface-Water Quality-Assurance Plan documents the policies and procedures of GMA that ensure high quality in the collection, processing, storage, analysis, and publication of surface-water data. Specific types of surface-water data discussed in this report include stage, streamflow, water quality, and sediment transport. The roles and responsibilities of GMA personnel for carrying out these policies and procedures are presented, as are issues related to management of the computer data base and issues related to employee safety and training.

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